COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

August 1951

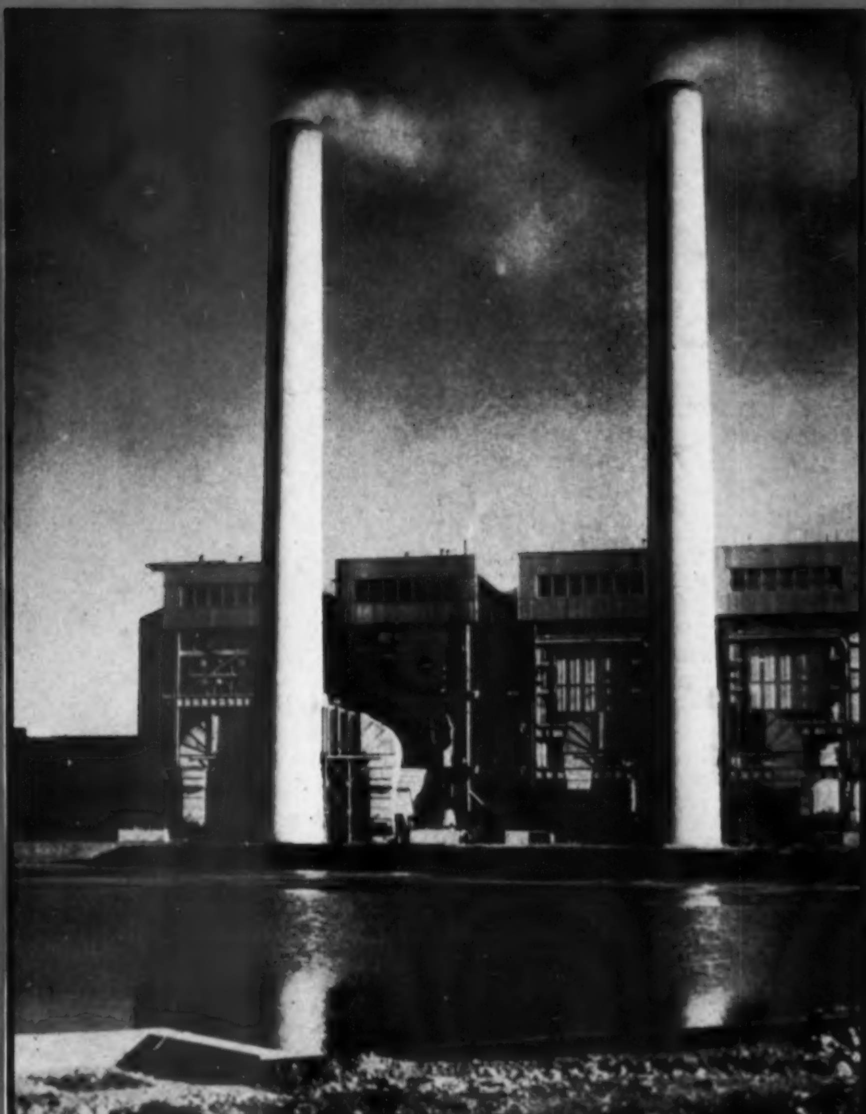
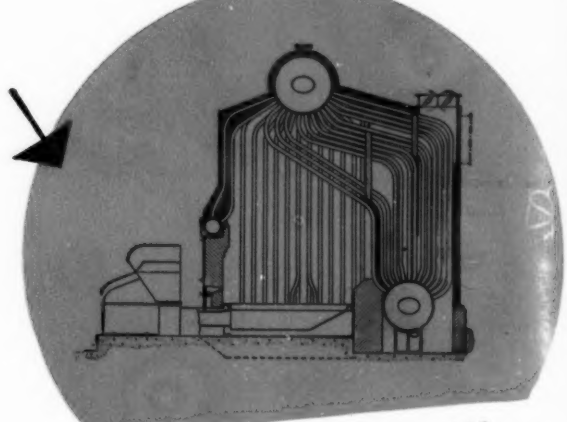


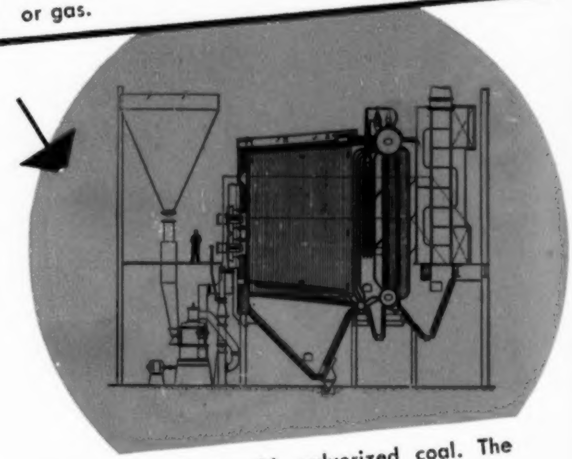
Photo by G. V. Thompson

As O. H. Hutchings Station appears today

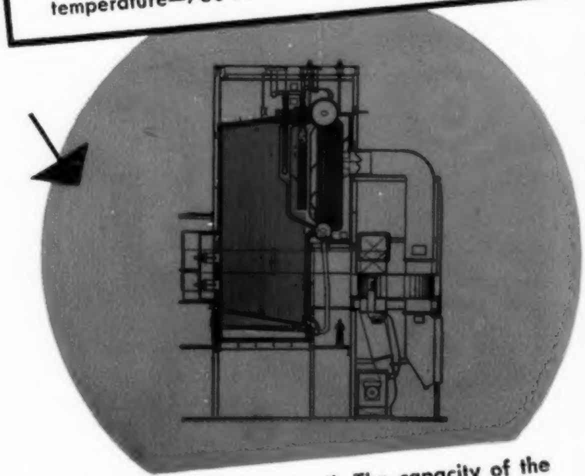
Are VU boilers habit forming?



VU-10 Boiler fired with C-E Skelly Stoker. VU-10 Boilers range in capacity from 10,000 to 60,000 lb of steam per hour. They may be fired by underfeed, spreader or chain grate stokers or by oil or gas.



VU-50 Boiler fired with pulverized coal. The capacity of the unit shown is 150,000 lb of steam per hour; operating pressure—625 psi; total steam temperature—760 F.



VU-50 Boiler fired with oil. The capacity of the unit shown is 350,000 lb of steam per hour; operating pressure—920 psi; total steam temperature —905 F.

The record shows that they are. More than 100 companies . . . large and small . . . throughout this country and abroad . . . have ordered VU units more than once. Nearly half of these have ordered more than twice. Some as many as 5 or 6 times.

Considered in light of the fact that Vertical-Unit Boilers have never been — nor are likely to be — the cheapest you can buy, such a record becomes even more significant.

Here are just a few examples of the many industries that appear to have formed the VU habit.

A Steel Company now has a total of eleven VU Units in three different plants. Starting with an initial installation of three units in 1940, it has reordered twice; three units for a second plant in 1946 and five units for a third plant in 1950.

An Electric Utility Company started using the VU in 1944 when two units were installed at one of their power stations. When the capacity of this station was increased in 1948 two more units were installed. In 1947 this company ordered two more units for another of its stations.

An Oil Company ordered its first VU in 1937, its second in 1938. In 1942 another VU was installed and still another in 1944.

An Aluminum Company is another consistent buyer of VU Units. Since installing its first VU in 1940, it has reordered four times, and now has five C-E Vertical-Unit Boilers in service.

* * *

Just a small sample to be sure, but one that can be repeated over and over for other industries and other companies . . . companies that have ordered and reordered VU Boilers . . . companies that have the "VU habit" and find it highly profitable. B-511A

C-E

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COMBUSTION

Editorials

Smoke in New York

As has previously been pointed out in these columns, New York cannot be classed as a "smoky city" in the generally accepted sense; yet it had sufficient atmospheric pollution from smoke and other contaminants to warrant adoption of a new ordinance which, after numerous hearings, became effective last October. Administration was placed under a Smoke Control Bureau whose director is an engineer of long and successful experience in this line.

Lately, enforcement of the ordinance has become the subject of much newspaper comment and attention from civic groups largely as a result of a divergence of opinion between the director and his deputy in the matter of enforcement policy. The former favors the cooperative approach with prosecution only as a last resort, whereas the latter leans to the "get tough" policy with all offenders. Naturally, the latter elicits popular acclaim.

Incinerators in office buildings and apartment houses, in the aggregate, undoubtedly account for considerable pollution in Manhattan, even though, individually, many of these may get by without violating provisions of the ordinance; and numerous offenders have been reported among industrial plants in the city and outlying districts. Fines have been imposed in some cases. Also, a number of city plants, particularly subway power plants and the municipal ferryboats, are well known producers of smoke and smudge.

It is most unfortunate that the director recently was quoted as advocating a soft policy toward certain offenders, including other city departments which, of all, should set an example for clean stacks. This immediately evoked renewed attacks by the daily press, although it is understood that subsequent violation notices have been served on certain city departments and hearings have resulted in promises of corrective measures.

A further announcement by the Smoke Control Bureau that henceforth the names of violators would not be given out for publication brought forth more criticism. There is something to be said on both sides of this question, but one is reminded of the remarks of H. G. Dyktor, Commissioner of Air Pollution for the City of Cleveland, who stated at the Annual Joint Fuels Conference last fall that when an offender in that city refuses to cooperate it is usually sufficient to invite newspaper publicity with pictures of his stack and it then becomes unnecessary to resort to legal measures.

What the public and the press fail to recognize is that, in a city such as New York, smoke is only one of many atmospheric contaminants which include dust, various fumes, exhaust from automobiles, sulfur dioxide, and unsaturated hydrocarbons; many of which are difficult to control. Moreover, the appearance of the atmosphere is affected by such factors as wind velocity, turbulence, humidity, temperature inversion, etc., all of which are now better understood as a result of research over the last few years. It is demonstrated by the clear atmosphere around New York that usually follows a heavy rain or a high wind. This is not to say, however, that smoke can be neglected. While the New York papers have overstressed the situation in order to carry on a campaign which they consider in the public interest, the net result may be beneficial, for it has focused attention on a situation that needed to be corrected.

The Utilities and Atomic Energy

Through the years the electric power industry and the manufacturers of power plant equipment have developed many mutually beneficial relationships. These have resulted, in part, from a general willingness to share technical and operating experiences. The consequence has been that engineering advances have been quickly tried out, with advantages accruing to both the electric power industry and the manufacturers.

Atomic energy with its prospective use as a future source of power cannot fit exactly into this ideal, informal relationship for reasons of national security. But steps are being taken to increase the participation of the utilities as proposed in a report, briefed in this issue, by the Advisory Committee on cooperation between the electric power industry and the Atomic Energy Commission.

It seems entirely reasonable that the first recommendation of the Advisory Committee should concern education, so that qualified personnel from the utilities can obtain a substantial background in reactor technology. In another direction, it is likely that the Atomic Energy Commission has special problems relating to heat transfer and coolants where the experience of technicians from the electric power industry will prove useful. Another area of mutual interest relates to utility economics, where much information must be collected on the capital, operating, and maintenance costs of reactors.

The report of the Advisory Committee points in the right direction. It is to be hoped that means will be found within security limits to promote the participation of the electric power industry along the lines recommended and that a permanent electric power industry committee will be set up to continue cooperation with the Atomic Energy Commission.

Emma Power Station of The Netherlands State Mines

The largest boilers in Holland are two 425,000-lb per hr C-E units going into service this September. Steam conditions are 1100 psig and 932 F at the superheater outlet. Designed for tangentially firing pulverized coal containing 36 per cent ash, a dry-bottom furnace is employed with one direct firing mill and two mills on the bin and feeder system. The electrostatic fly-ash precipitators are outdoors. There are two topping turbines, one driving a 22,200-kw generator and the other a 15,000-hp unit driving the largest European rotary compressor for air supply to coal mine Emma. Existing low-pressure condensing units in the old station take exhaust steam at 214 psig.

By DR. IR. F. W. VAN BERCKEL

Chief Engineer, Netherlands State Mines

RAW materials in the Netherlands, with its very dense population of ten million on 12,900 sq mi, are very scarce. Coal is the principal richness of its soil, and is mined in a small area in the province of Limburg, between Belgium in the West and South and Germany in the East, only a few miles from Aachen and west of the coal fields of the Ruhr. Total annual output is 12 million tons, although the Netherlands consumes 16 million tons. What is probably Europe's oldest coal mine is found in this area in Kerkrade, near Heerlen, where the monks in 1113 discovered what they called "flammable earth." The abbey of Rolduc was founded in 1104.

The French revolution brought an end to this industry which was revived in 1896 by private French enterprise and capital. Later the Netherlands Government took an interest in the coal industry and the "Staatsmijnen," or State Mines, were formed.

The first state colliery was built in 1905 and employed electrically driven extraction machines, a rather bold step at that time. The power station initially contained two 300-kw units, which were soon followed by an 850-kw turbine-generator. Concurrently electricity supply to the city of Maastricht began. (This city was the first city in Holland liberated by the American armies in September 1944.)

Power is sold to the "Stroomverkoop Maatschappij," now the "Provinciale Limburgse Electriciteits Maatschappij" (PLEM), which company owns the distribu-

Fig. 1—View of the Emma power plant

Fig. 2—Model of plant exterior

tion system through the province. It now has a maximum demand of 70,000 kw.

In Limburg there are four private mines and four state mines. The latter produce coal having a variety of qualities, including an excellent coking coal.

Growth of the State Mines has been rapid and production has now reached seven million tons per year. The largest mine, as well as one of the largest in Europe, is mine Maurits, with an annual output of nearly three million tons. Mine Emma and mine Maurits have large coke-oven plants and, near the latter, chemical works were erected for the production of fertilizers. Hence, more power was needed at an ever-increasing rate.

In 1950, electric production reached 1127 million kilowatt-hours, of which 208 million was delivered to public consumers by PLEM. Load of the chemical plants is increasing rapidly and is estimated to reach 100,000 kw by 1955.

In 1913, a power station with hand-fired boilers and units of 2000 kw was erected at mine Emma and a system of 10,000-volt cables was laid between the mines. Steam pressure at that time was only 200 psig.

The power station at mine Maurits, containing two 8000-kw, 400-psig, 710-F units, was synchronized with the system in 1927. Now a total capacity of 154,000 kw is installed in the Maurits plant and a 300,000-lb per hr natural circulation boiler with the highest pressure in Holland of 1650 psig will start operation in September 1951.

Compressed air is much used in the Netherlands mines. Most of the coal layers are only 3 to 6 ft thick and mining is difficult, hence the miners use air-driven hammers and either electrically driven belt conveyors or air-driven shuttle conveyors. The mine power stations have large air compressors, at present all of the rotary type and driven by steam turbines. Air pressure is 100 psig.

Following the war, mechanization of coal mining was given intense study and much progress has been made toward increasing production or keeping up production with less skilled labor, as it has become more and more difficult to find the necessary manpower.

Rapid growth of population and industry in the area served by the mine power system, as well as in the other provinces, has created a need for additional generating capacity, but materials were in short supply and periods of construction by European manufacturers were long.

The power stations at mines Emma and Maurits lacked space for further extension with condensing units. The existing boiler installation at mine Emma contained out-of-date, low-efficiency units, but they could not be removed to permit replacement because every pound of steam was needed. However, the existing turbine-generators and turbo-compressors were relatively modern and their capacity exceeded the available boiler capacity.

A study showed that increased generating capacity could best be accomplished by topping the existing plant,

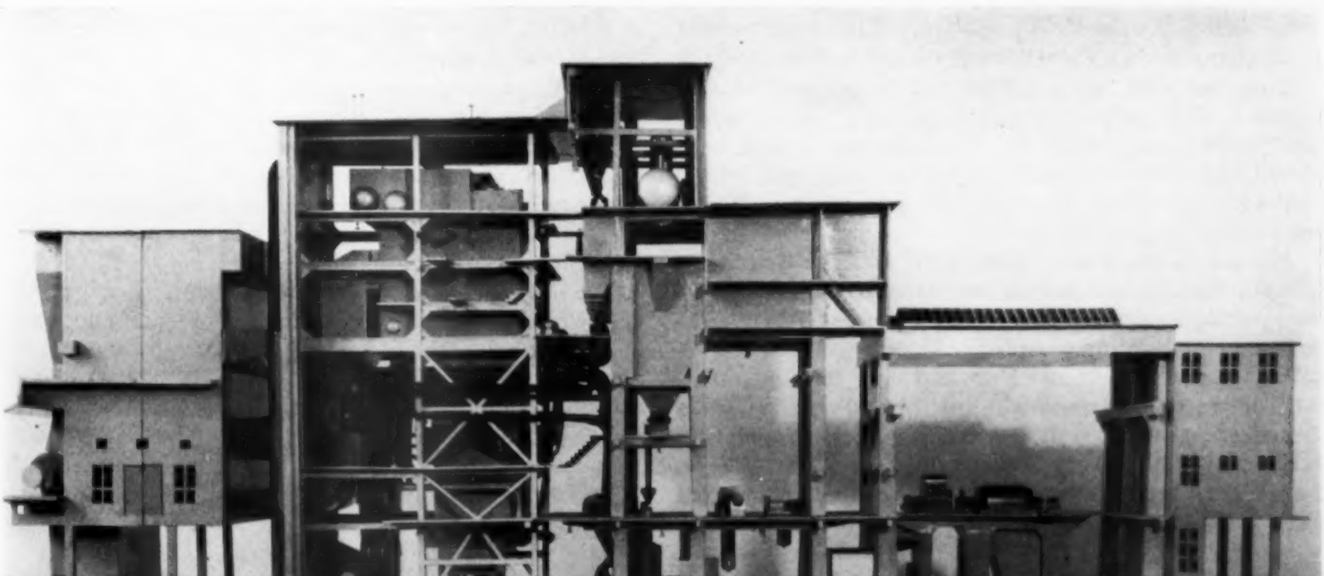

Fig. 3—Model section of plant

which operated at 200 psi, 625 F. Space for a topping plant was available some 350 ft distant on the site of an old coke-oven plant, which had been partly dismantled. The highest steam temperature in operation in a small plant in the Netherlands was 500 C (932 F) and for new equipment the trend here was toward conservatively designed conditions of around 930 F at the superheater outlet and a steam pressure of 1200 psig at the safety valves. Economic and technical studies indicated that steam conditions of 1000 psig and 900 F at the turbine throttle were right for this installation.

A topping unit of 22,200 kw capacity at 74 per cent power factor, designed for 3-phase, 50-cycle, 11,000-volt operation was selected, as well as a rotary air compressor of 74,000 cfm at 114 psig, driven by a 15,000-hp turbine. The turbine-generator has a steam consumption of 555,000 lb per hr and the turbo-compressor 265,000 lb per hr; hence two boilers of 425,000 lb per hr size were selected.

All coal at the collieries is washed and carefully treated. To permit the washery to deliver a product as wanted by customers, a middlings product also becomes available. This is high in ash content (from 20 to 45 per cent) and is not marketable but can be fired economically at the mines to produce steam and power. Preliminary tests had shown that fuel containing up to 40 per cent ash could be pulverized and fired. Twenty years of experience with pulverized coal at the Maurits power station made it easy to choose pulverized coal as the primary fuel for Emma, although oil and gas firing were provided for lighting up and as standby fuels.

Site, Building and Coal Handling

Although there is no nearby river water available, the site meets the requirements for erection of cooling towers should a condensing unit be added later, with space becoming available through further dismantling of the old coke-oven plant. No stockpile is provided, nor are coal crushers necessary, the coal being delivered by rail with very modern 20-ton side-dumping cars. The coal is discharged to a steel belt conveyor in such a way that different kinds of coal can be mixed. This belt feeds a vertical bucket conveyor which discharges into a 2000-ton capacity reinforced-concrete storage bin. The coal bunker feeds an inclined single belt conveyor having a capacity of 150 tons per hour, and which reaches the new boiler house at the top of the precipitator structure. This inclined bridge will be seen in Fig. 1. The conveyor is totally enclosed and of the standard construction employed by the State Mines. Some 30 miles of such belt conveyors are used in the underground works.

All coal to the station is weighed and the weight recorded, the coal first passing beneath a strong magnet to remove tramp iron.

The main building comprises offices, wash and recreation rooms, a turbine room, an auxiliary bay, an auxiliary substation and a boiler house. An adjacent building houses a maintenance shop, a warehouse, and a chemical laboratory. All, except the boiler house, are of reinforced concrete, as are the raw coal and pulverized coal bins. The boiler house is a steel structure with the roof supported by the boiler columns.

The subsoil is good and piling was not necessary, but the whole building structure had to be divided into sections with separate joints to take into consideration soil movement due to underground mining. Design of the plant was facilitated by scale models (Figs. 2 and 3). Another model of the piping bay was of much assistance in the drawing room. The turbine house has an access bay for entrance of railroad cars and the crane is laid out for a future extension accommodating a 50,000-kw condensing unit.

Steam Generation

The existing twenty-four pre-war boilers in the old plant have a total steam capacity of 660,000 lb per hr, but the new topping turbines require 814,000 lb per hr. The new boiler plant contains two 425,000-lb per hr C-E three-drum steam generators designed to deliver steam at 1100 psig and 932 F at the superheater outlet. All pressure parts are calculated to withstand 1450 psig at the drum safety valves and thus a large margin is available between drum pressure and that at the turbine inlet. A standard design was chosen and the boilers were ordered in the beginning of 1947 with Messrs. N. V. Koninklijke Maatschappij "De Schelde" at Vlissingen, Holland, as main contractors. All pressure parts, such as drums, tubes and headers, as well as the air heaters, economizers and superheaters, burners, valves and fittings, pulverizing equipment and boiler steel structures, were supplied by Combustion Engineering-Superheater, Inc., New York. The casing, air ducts, all fans, the brickwork and insulation, and the erection on site were executed by "De Schelde," or by its subcontractors. Motors, instruments and much other equipment were purchased by Staatsmijnen. A sectional elevation of the new power station is shown in Fig. 4, and a plan of the operating floor in Fig. 5.

The steam generators are the first of American design in the Netherlands, as well as the largest in capacity. They were followed by four 285,000-lb per hr units for the "Amer" power station and one of 255,000 lb per hr for the power station at Groningen.

The furnace, which has a gross volume of 29,200 cu ft with a maximum average heat release of 18,200 Btu per cu ft per hr, is completely water-cooled with plain tubes of 3 in. O.D. on 3 $^{1}/_{8}$-in. centers. The front drum measures 48 in., the rear drum 54 in. and the lower drum 36 in. I.D. A bubble-type steam washer and a screen dryer are provided in each unit. Boiler feed is condensate from the existing low-pressure condensing units in the old plant and the steam purity is guaranteed not to exceed 1 ppm.

There are four Consolidated safety valves on the main steam drum of each unit and two on the superheater outlet header. Also, there is a remote-controlled safety valve on the superheater header which can be operated from the main control room.

The interbank Elesco superheater has two stages, the low-temperature first stage consisting of 62 nine-loop elements of low-carbon steel and the high-temperature second stage 80 two-loop elements. The hottest part of the superheater is of chrome-molybdenum steel tubing, titanium stabilized.

Steam temperature is held constant by a Leeds & Northrup electrically operated system which automatically regulates the position of the nozzles of the burners and the superheater bypass damper.

A set of series dampers operates in combination with the bypass damper and their position is indicated on the main control panel. Steam temperature will be regulated by raising or lowering the burner nozzles in the four

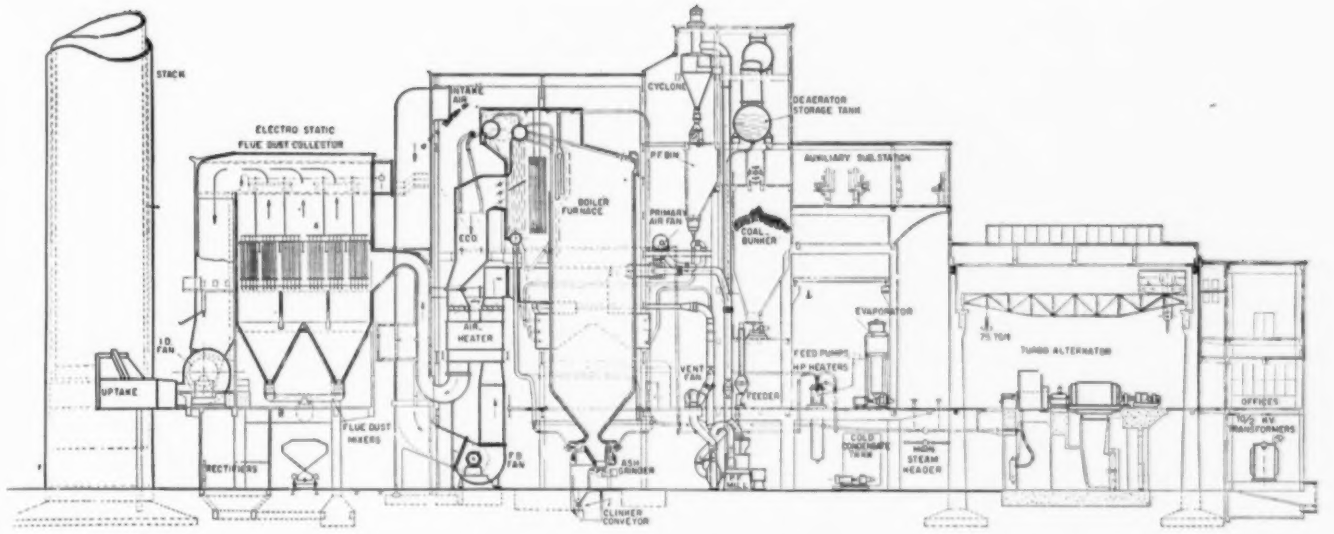

Fig. 4—Cross-section of the plant

corners of the furnace simultaneously by motor-driven actuators. These actuators are synchronized and each burner will be tilted to the same angle. At a certain degree of tilting above or below the horizontal the dampers come into action automatically. Steam temperature is guaranteed at 932 F plus or minus 10 deg for the range of 225,000 to 425,000 lb per hr.

Each corner of the furnace has a C-E tangential type coal burner incorporating three tilting nozzles under remote control and a pressure-atomizing oil burner. Lighting off is done by automatic electric pilot torches. Also, two of the burners have gas nozzles for use if excess gas from the nearby coke ovens is available. The lower burner nozzle is supplied with coal from the direct-fired mill, whereas the middle and top nozzles are fed by coal from the feeders of the pulverized fuel bin of the storage system. The direct-fired mill will be used on a base load.

The economizer has finned tubes arranged for counterflow with a total heating surface of 10,990 sq ft.

The vertical Ljungstrom regenerative air preheaters each have a heating surface of 70,700 sq ft, and are designed to provide hot air of 672 F at maximum continuou load.

Each boiler is served by a raw coal bunker of 390 tons capacity having three circular 3-ft bunker outlets, each with a table feeder as shown in Fig. 6.

These large outlets were chosen to prevent arching and to make the bunker self-cleaning. The coal to be burned is high in moisture and rather fine which promotes sticking.

It is the practice of Staatsmijnen to provide large openings under coal bunkers to prevent clogging. However, a difficulty arises when a pulverizer feeder with a rather small inlet has to be connected to the bunker. Moreover, a coal seal above the mill feeder is necessary because the mill is under suction. It was therefore decided to place the Raymond mill feeder close above the pulverizer but on the operating floor and thus to make the spout to the mill as short as possible. The coal pipes between the table feeder and the mill feeder have a jacket with an inlet and an outlet for preheated air to keep the inner pipe hot. This minimizes clogging of wet coal.

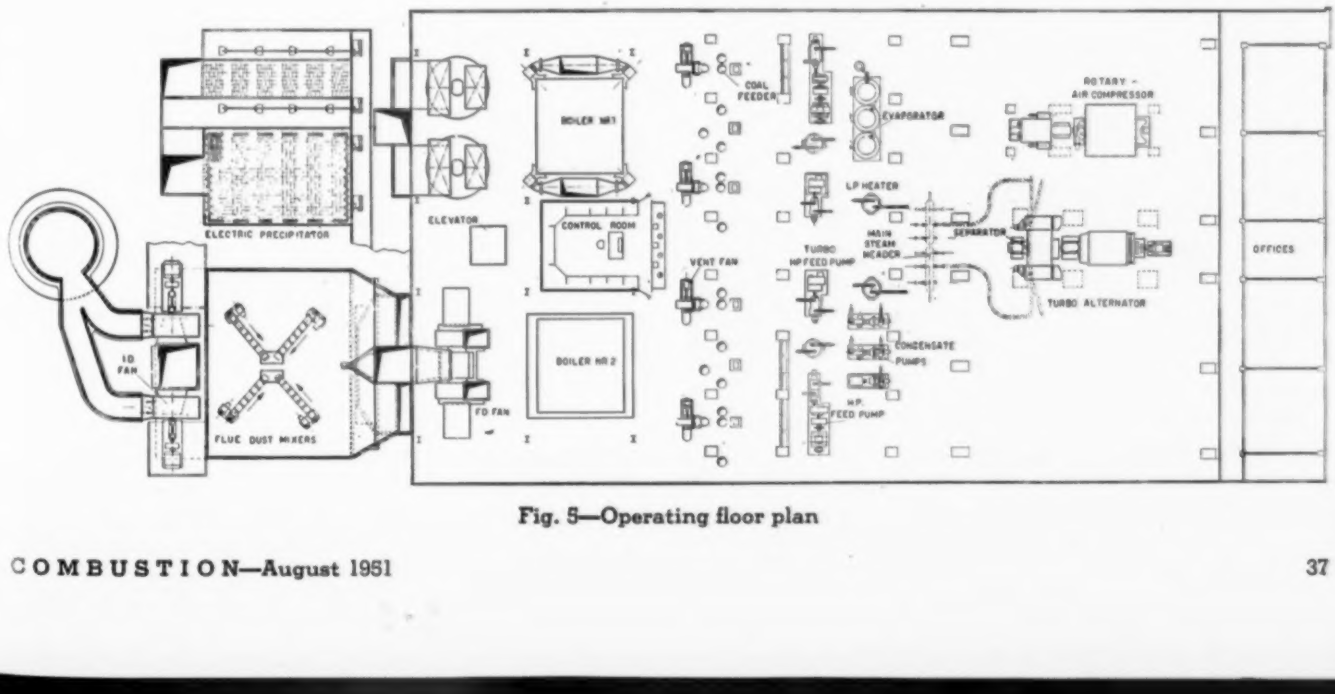

Fig. 5—Operating floor plan

Above the mill feeder is a small $^1/_2$-ton coal hopper. The flow of coal delivered by the table feeder can be adjusted manually from the main operating floor. Mills Nos. 1 and 3 feed the pulverized coal bins and have a constant feed independent of changes in boiler load. It was anticipated that it would be an easy matter to adjust the flow of coal in such a way that the level in the small coal hopper could be kept practically constant. However, if the supply from the bunker should become too great, the coal level would rise and finally reach the outlet of the table feeder. This had to be prevented. Therefore, as soon as the hopper is full the table feeder will be automatically stopped by a "high level" switch. When the level drops again under this upper level, a time-relay, after some minutes, starts the table feeder again. There is also a "low level" contact which actuates an alarm in the main control room.

The pulverized fuel bins have no "low level" indicators, but instead a hand-operated device to measure from time to time the level of the pulverized coal. A "high level" alarm warns the operator to prevent overflow of the bins. There are no scales between bunker and pulverizers.

Pulverizing Equipment

The pulverizing equipment consists of three C-E Raymond bowl mills each driven by a 250-hp, 1000-rpm motor which also drives the exhauster. Each mill has a capacity of 9100 kg per hr (approximately 20,000 lb) of dry pulverized coal to a fineness of 80 per cent through 200 mesh. The Hardgrove grindability ranges from 70 to 80.

The existing power station at mine Maurits, designed in 1925, has eight boilers fired by pulverized coal with bin and feeder (storage) system and separate drying and pulverizing plant. Serious thought was given to direct firing at Emma Station but finally the bin and feeder system was chosen for two mills and direct firing for the third, due to the following considerations:

The fuel is rather low in volatile and there was no experience with tangential firing in Holland, where the usual practice for low volatile coal (10–12 per cent) is to employ vertical firing (U-flame) and furnace walls covered by refractory blocks.

Since there were to be only two steam generators in the station utmost availability was aimed at because forced outage of such a large boiler (425,000 lb per hr) could have serious consequences, even though the Emma Station is connected to other power stations of the system. The next largest boilers on the system, at Maurits, are only 200,000 lb per hr rating. Steam production is also very essential for the steam-driven compressors because coal output is dependent on the supply of the mine with compressed air.

It is well known that the bin and feeder system allows the use of a small quantity of primary air which facilitates ignition. A pulverized fuel bin furthermore makes the boiler more independent of outages of the pulverizing equipment. However, the bin and feeder system is more costly and complicated than direct firing and it appeared worth while to try out the latter with one mill on each furnace.

The four cyclones are placed on top of the pulverized coal bins, each of which has a capacity of 25 tons. Each cyclone has an outlet to the bin or can be switched over to a screw conveyor with passes underneath the four cyclones of both steam generators. The screw conveyor carries pulverized coal from one cyclone outlet to another and thus to each bin in case of emergencies and for starting-up where a bin is completely empty.

Vent air is drawn off by two fans which deliver the moisture-laden air to four corners of the furnace through ports provided above the coal stream.

Fly Ash Precipitators

The electric load of the State Mines is a typical base load and the new Emma plant with topping units will have a high load factor.

Estimating an average boiler load of 365,000 lb per hr, a fuel containing 36 per cent ash and 20 per cent clinker collected in the furnace hopper, fly-ash going up with the furnace gases, inclusive of 15 per cent unburnt carbon, amounts to approximately 77 tons per hour. Therefore, it is obvious that without a highly efficient dust collector the nuisance to the surrounding area, not to mention wear on the fan blades, would be unbearable.

Extensive studies were made of multi-cyclone mechanical dust collectors, electrostatic precipitators, settling chambers, and combinations of cyclones and filters. Under the circumstances, electrostatic precipitators with their low gas velocities seemed to offer advantages. Therefore, it was decided to install for each boiler an electric precipitator in two parallel compartments, each having 625 nests of vertical circular tubes 10 ft long, with a coaxial wire as discharge electrode connected to the high-voltage source. The dust-laden gases pass upwards through the tubes. Fig. 7 shows tubes of one compartment at the outlet side. Underneath the tubes are large fly-ash bunkers, adequate storage being necessary because during week-ends shipping of the dust has to be avoided.

The precipitators were furnished by the Carbonisation et Charbons Actifs S. A. at Paris. They are each designed for handling up to 3600 cfs of gases at 330 F at an overall efficiency of 92.5 per cent, a fractional efficiency of 97 per cent on dust above 35 microns and at a carbon content in the grit up to 40 per cent. With 15 per cent carbon the efficiency of precipitation will rise to 95 per cent.

At normal load the overall efficiency is guaranteed at 97.5 per cent with 15 per cent carbon in the flue dust. The dust content in the entering gases varies from 11.5 to 38 gram/m^3 (5–16.5 grains per cu ft), influenced by the ash content of the fuel and the carbon content of the dust. Maximum gas velocity in the tubes is approximately 5 ft per sec.

Each precipitator has two rectifiers which, together with the high-tension transformers, are mounted at ground level in the basement. As can be seen from Fig. 4, gases leaving each air heater pass through a 180-deg bend and then upwards through a vertical duct to the corresponding compartment of the precipitator. This dust cloud has a rather small cross-section (39 sq ft) with a gas velocity of 45 ft per sec at maximum boiler load, and the aerodynamic design prevents precipitation of dust in the lower 180 deg bend, as removal of this dust would be inconvenient.

A horizontal bypass duct permits manually operated louvre-type dampers to combine the gases from both air heaters and to pass the total volume through one section of the precipitator, in case of a forced outage of the other

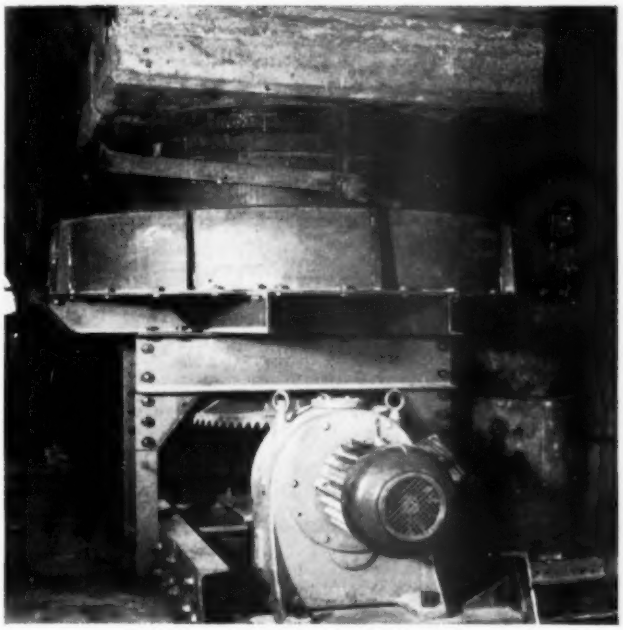

Fig. 6—Table feeder under raw coal bunker

Fig. 7—Outlet of the tubes of electrostatic precipitator

Fig. 8—Flue dust mixers

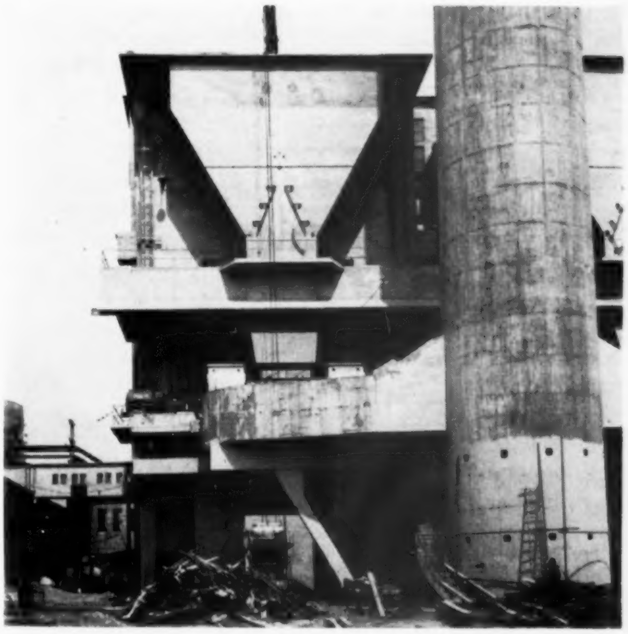

Fig. 9—Precipitator with outlet gas duct to twin I.D. fans

Fig. 10—Main steam header with branches

section. Under such conditions the efficiency would be somewhat lower for a given boiler load.

Handling of Flue Dust

Handling and elimination of the flue dust offered several problems, not only where to deposit the expected 90,000 tons a year but also how and in what form. The solution finally chosen consists of a series of four dust mixers underneath the outlets of the four hoppers of each precipitator.

The mixer consists of a steel trough enclosing a shaft with propeller-type wear-resisting paddles. At one end the dust is fed in by a rotary feeder and is wetted after some traveling by water sprays along its way to the other end. The four flue dust dampeners center toward a common outlet above the middle of the railroad track. Special side tilting railroad cars are provided and the distance between the two outlets for conditioned dust equals that of the distance between the centers of two cars. This is convenient for discharging two precipitators simultaneously with a set of four mixers. The train with railroad cars can be slowly moved during discharging to fill the cars along their whole length.

Disposal of the dampened ash is on a dump site where it is sandwiched between refuse from the washery colliery. This keeps the dust from drying out and becoming a nuisance.

The four flue-dust dampeners of one precipitator are shown in the plan, Fig. 5, and in Fig. 8.

To prevent condensation in the flue dust hoppers which might interfere with the flow of the dust, the hoppers are protected from cold winds and totally enclosed by walls. Furthermore, they are constructed of reinforced concrete and lined outside with insulating bricks.

Fans

The forced-draft fans are set at ground level in the boiler house basement but draw air from the top of the boiler house to assist ventilation and to regain some heat. Each steam generator has two single-inlet fans driven at 1435 rpm by a 225-kw, 2000-volt motor through a Vulcan Sinclair hydraulic coupling furnished by Hydraulic Coupling & Engineering Co. Ltd., England. The capacity of each fan is 2100 m^3/min. (74,500 cfm) at a static head of 12 in. The hydraulic couplings are controlled from the main control room.

Dampers are provided to separate each air heater from the system at the gas and air side if forced outage should occur and an air heater has to be stopped.

The two induced-draft fans are located outdoors on a platform integral with the building structure of the precipitators. Each is driven at 955 rpm by a 257-kw, 2000-volt motor through a hydraulic coupling. The fans are single inlet and have vane control. Each has a capacity of 114,000 cfm of gas at 165 C (330 F) against a total static head of 11.5 in. w.g. Best guaranteed efficiency is 82 per cent.

Flue gas from both steam generators is discharged into a common reinforced-concrete, ground-supported, fully lined, tapered stack 80 m (260 ft) high.

All ductwork from the outlet of the air heaters to the stack and the whole structure of the precipitator are of reinforced concrete. All walls of the precipitator and of the fly-ash bins are insulated with porous bricks to keep the wall surface above the dewpoint and to prevent excessive temperature differences between outside and inside surfaces of the concrete which may cause cracking. Misalignment between stack and the structure of the precipitator is taken up by an elastic connection at each fan outlet.

Ash-Handling System

The ash-handling system is of unconventional design and consists of three "Martin" type ash grinders connected to three brick-lined hoppers across the width of the main furnace hopper. They are of German design and each has a capacity of approximately 2.6 tons per hour. The grinder consists of two slowly rotating toothed rolls.

The broken clinker falls into a small water-filled hopper just underneath the grinder rolls which forms a waterseal and from which a pusher delivers the clinker out of the hopper and through a vertical spout to a belt conveyor which transports it into an overhead bunker.

Soot Blowing

A Vulcan steam soot blower system is employed and for each boiler consists of six air-operated retractable units of approximately 77 ft travel. These are installed at the sides of the casing near the superheater loops. Also, eight hand-operated blowers have been mounted on the boilers and superheater sections and eight units on top of the economizer and between the groups of economizer tubes. Eighteen wall blowers can be installed in the future if this should become necessary. Saturated steam for blowing is supplied at 200 psi.

Fly ash from the hopper under the superheater is blown back into the furnace through three nozzles, each equipped with a fan delivering against a static head of 12 in. w.g. The nozzles are placed in the back wall of the furnace at burner level. The fly ash can also be delivered to the cinder-disposal system.

Feedwater Cycle

A flow diagram for the new plant is shown in Fig. 11. Condensate from the existing condensing units is delivered at 120 to 160 F to two steam-sealed storage tanks at ground floor in the auxiliary bay. These supply the booster pumps which send the condensate through two low-pressure closed heaters into the deaerator tanks, of which two, with a net capacity of 62 tons, are provided above the inlet of the feed pumps, as shown in Fig. 4.

The deaerators are designed for 71 psi pressure. One receives steam from a bleed point on the turbine of a 20,000-kw condensing set and the other from an extraction point on the turbine of a 25,000-kw set in the old station. Since the steam pressures at the bleed points are normally not the same, the steam pressures in the deaerators are different and they cannot be connected.

At low load on the condensing units the quantity of extraction steam is insufficient, hence steam at 215 psi will be automatically reduced to supply steam for heating the condensate in the deaerators.

Boiler Feed Pumps

Two barrel-type, six-stage pumps, manufactured by Messrs. Sulzer, Winterthur, Switzerland, each having a

maximum capacity of 240 tons (530,000 lb) per hour of 150 C (302 F) feedwater against a total dynamic head of 1540 psi and two seven-stage pumps manufactured by Messrs. Stork, Hengelo, Holland, with vertically splitring casing, having a maximum capacity of 240 tons per hour against 1270 psi, are located in the auxiliary bay on the main operating floor. The Sulzer pumps are steam-driven by back-pressure turbines through a step-down gear with throttle steam of 215 psi and 10 psi back-pressure. The exhaust steam is utilized for heating the low-pressure condensate heaters, the hot water heating system of the power plant, and the main buildings of the colliery.

and one steam-driven pump, but between the supply lines a cross-over is provided as shown in the flow diagram, Fig. 11. The gate valve in the cross-over of the high-pressure boiler feed lines is normally closed. In this way pressure is held on one unit if the other boiler feed system should lose pressure. One boiler feed pump is sufficient to meet full load on the steam generating unit.

Before entering the economizer the feedwater passes through a vertical high-pressure heater, designed for 1700 psi on the water side and 270 psi on the steam side. These heaters have 1 in. O.D. cupro-nickel U-bent tubes and a wall thickness of $^1/_{25}$ in. The condensate is discharged to the deaerator tanks.

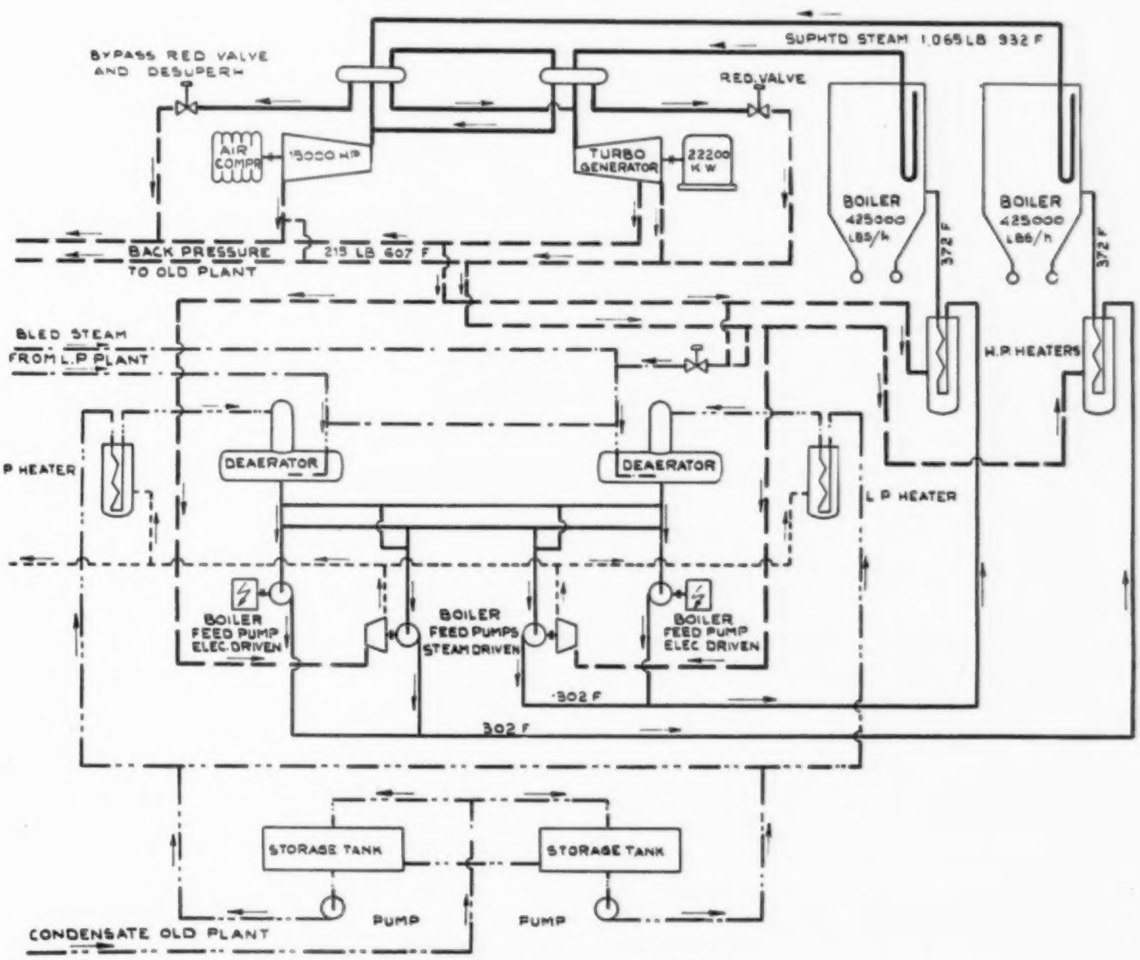

Fig. 11—Flow diagram of feed cycle

The Stork pumps are electrically driven by 950-kw, 2000-volt, 1500-rpm motors through a Vulcan Sinclair hydraulic coupling and a step-up gear with 3600 rpm at the pump shaft.

All pumps have internal parts of monel. The barrel of the Sulzer pumps is of forged steel and the rings of the casing of the Stork pump are of special cast iron.

No bypass control system for maintaining minimum flow through the pumps is provided, since the leakage of the balancing disk is counted upon to prevent overheating of the internal parts at low load. A hand-operated valve is provided to sluice away a flow of water to the storage tanks and cool the pumps in case of emergency.

Each deaerator tank supplies one electrically driven

Makeup Evaporator

A three-effect evaporator, designed by Messrs. Aiton of Derby, England, is equipped with an auto-compressor using live steam at 212 psi and compressing approximately half of the vapor of the third stage at 1 atm to steam pressure of 1.7 atm abs. (25 psi) at the first stage. Thus, only half of the steam leaving the third stage has to be condensed in an evaporator feed heater. Feedwater for the evaporator is prepared in a cation exchanger.

Piping and Valves

The Emma plant is one of the first power stations in Europe using welded-in valves for high-pressure steam

and feedwater piping. Such valves were furnished by the American firms, Lunkenheimer Co., Manning, Maxwell & Moore, Inc., Walworth Co., and Edward Valves, Inc., and by Dikkers of Hengelo, Holland. Valve bonnets are of the pressure-seal or breechblock design. Gate valves are of the wedge type and were preferred above the parallel slide valve which is almost universally used in European power stations for high-pressure steam and feedwater service. All valves have stellited seats. All welds have backing rings and were preheated and stress-relieved by an electric induction heater.

The main steam piping is chrome-moly alloy steel ($^1/_2$ per cent Cr, $^1/_2$ per cent Mo) and the high-pressure feed piping is carbon steel. The velocity in the line to the economizer for 425,000 lb per hr is 11.6 ft per sec, and the steam velocity in the main steam line at maximum boiler load is 180 ft per sec. The main steam headers, located in the auxiliary bay midway between the boilers, are interconnected by a loop. They are fabricated of seamless chrome-moly steel tubing with the ends closed by forgings (see Fig. 10). The header has an inside diameter of 380 mm (approximately 15 in.) and a nominal wall thickness of 45 mm ($1^3/_4$ in.). The branches are formed by extruding the wall of the header and welding on a sleeve. Near the branches the header is all around reinforced by shrinking on of a ring.

At each main steam header a desuperheating and reducing station, supplied by James Gordon, is provided to furnish steam at 15 atm and 310 to 350 C (220 psig, 590 to 660 F) to the exhaust lines of the topping turbines if it is desired to bypass them. The reducing station has Hagan air-operated automatic desuperheating and pressure control.

All valves are hand-operated. A three-element Bailey feedwater regulator serves each boiler and the bypass of the regulator valve is under manual control.

In order to have at different boiler loads a moderate and constant pressure drop over the feedwater regulator valve, a differential pressure relay across the feedwater regulator serves to control the speed of the hydraulic coupling driving the boiler feed pump or alternatively actuates the governing valves of the steam-driven feed pump. In normal operation one feed pump is running at full load on the steam generator.

The differential pressure relay is mounted in the control room, the medium used for control of the hydraulic coupling or the governing valves being oil under pressure.

Instruments and Combustion Control

The air-conditioned main control room is situated at the operating floor between the boilers and employs indirect lighting. Three sides of the room are occupied by the instruments controlling the boilers, pulverizers, fans and other auxiliaries and the fourth side has a benchboard with windows above the board, through which the main aisle in front of both boilers, the turbine room and the auxiliary bay are visible. On the benchboard are mounted the electrical controls for the generator and for the direct-current auxiliaries for speed regulation of the pulverized coal feeders.

Both steam generators have complete Hagan automatic combustion control. This does not regulate the pulverizers but actuates the speed of the four pulverized fuel feeders under the bins. These feeders are simultaneously driven through d-c motors by Ward Leonard control. The speed of each feeder can be adjusted in the main control room and speed indicators are provided.

The quantity of vent air from the pulverizers serving the bin and feeder system is manually operated by a valve at the inlet of the vent fan. According to the moisture content in the coal and the coal feed to the mill, more or less vent air is necessary. Furthermore, hot air must be supplied to the mill to maintain a constant temperature at the outlet and to prevail excessive moisture in the pulverized fuel. The quantity of preheated air to the mill is automatically regulated to maintain suction in the mill at all times.

The mill for direct firing is operated from the main control room. Coal feed and quantity of preheated air have remote control. Temperature control is accomplished by regulating the position of the damper in the hot-air duct and the tempering air damper at the mill inlet holds the mill under a slight suction. Each topping turbine, as well as the air compressor, has a separate instrument and control panel located near the unit.

The feedwater system is provided with control panels for each group of feed pumps, heaters and deaerator belonging to each steam generator. The reducing stations are operated from panels in the auxiliary bay.

Turbine-Generator

This 22,200-kw, 3000-rpm machine comprises a single-casing, twelve-stage Escher Wyss reaction turbine having one Curtis velocity stage and a 10,800-volt, 30,000-kva air-cooled alternator supplied by Messrs. Smit, Slikkerver, Holland.

Steam to the first-stage nozzles is admitted by three governor-controlled valves and a fourth valve admits steam to the first reaction stage as soon as a load of 20,000 kw is reached.

Each of the two steam chests contains a stop valve and two control valves. The blading is of high chromium heat-resisting steel and the turbine cylinder is of molybdenum cast steel, equipped with electric heating elements outside the lower turbine cylinder to equalize metal temperatures in the upper and lower sections of the cylinder during starting-up periods.

With throttle steam of 70 atm 490 C (1030 psig, 914 F) the turbine exhausts at 15 atm (220 psig).

Turbo-Compressor

The turbo-compressor, built by Brown Boveri, has a turbine of 15,000 hp at 3500 rpm directly connected to a nine-stage radial air compressor delivering 4,416,000 cfm at a pressure of 8 atm (117 psig). The unit is the largest single-cylinder compressor built by Brown Boveri. After each stage, except the first and the last ones, the air is cooled, the interstage coolers being placed underneath and on top of the compressor housing. The compressor has two sets of opposed impellers to lower the axial thrust and to avoid use of a high-pressure stuffing box against atmospheric pressure.

Particular attention was given to the regulating system and to safeguard operation. Devices are installed to regulate speed and back pressure, to maintain constant air pressure and to guard against pumping. The unit is further protected against overspeed, axial displacement of the rotor, abnormally high back pressure and excessively high temperature of the compressed air.

It is well known that rotary compressors start to "pump" as soon as the delivery of air drops below a certain limit and the air pressure drops below the pressure in the receiver. Compressors of high efficiency have a pump limit which is rather close to the normal capacity. To avoid the phenomenon of pumping at any load the following interesting device has been installed:

An air turbine is mounted on one end of the shaft of the compressor. It consists of a single-row velocity stage with a governing system employing three oil-operated control valves. This turbine is supplied by air under pressure from the outlet of the machine as soon as the load on the compressor falls below a predetermined volume of air. "Pumping" is thus avoided because the flow through the impellers of the compressor is kept constant by discharging more compressed air through the air turbine, as the supply to the mine diminishes. The expanding air gives up power and is discharged to atmosphere. Part of the compression power of the unused compressed air is thus regained as mechanical power at the compressor shaft.

The station is served by existing hyperbolic cooling towers, the first hyperbolic cooling tower of reinforced concrete having been erected at State Mines as early as 1920. Since then, many similar towers have been built, mainly in Holland.

Electrical Features

The main generator in the new station is connected by 10-kv cables to the totally enclosed busbars at the existing station. The oil-circuit-breakers are of the draw-out and plugging-in type.

Power for auxiliaries is supplied by a house-service machine. Two units in the existing station, one 7000 kw set, the other a 10,000 kw set, are available for this purpose. Normally, only one machine is running. The house set feeds a 10-kv busbar to which 10/2-kv auxiliary transformers are connected. In normal operation the auxiliary system runs parallel with the main system through a circuit-breaker. In the event of loss of voltage on the main system and in case the bus voltage has dropped to approximately 7000 volts, the busbar of the house generator is instantly separated from the main system.

All auxiliary motors above $^1/_2$ hp are supplied at 500 volts, and those above 70 hp at 2000 volts. All start across the line. Throughout the plant alternating current is used; 3000 kva transformers adjacent to the new power plant step down power from the 10-kv busbars and feed to 2000-v metalclad busbars with horizontal draw-out oil-immersed circuit-breakers.

The auxiliary substation with 2000-volt and 500-volt switching apparatus is located in the auxiliary bay which has no windows in order to protect the relays against dust and to keep the substation clean.

All switching is done from the main control room and all motors can be stopped, but not started, by pushbuttons near the motor in case of emergency.

As soon as the new steam generating equipment is in regular service and reliable operation is assured, the low-pressure feed pumps of the existing plant will be moved to a new location in the new plant; the existing hand-fired boilers will be scrapped. The seven low-pressure stoker-fired boilers will continue to serve as reserve capacity. A low-pressure deaerator serving the condensate for the low-pressure boilers is necessary because the low-pressure section cannot handle the feedwater at 190 C (384 F) of the high-pressure station. In case an extra amount of condensate is wanted, the low-pressure boilers can be fed by chemically treated feedwater and serve as evaporators.

The capacity of the modernized Emma plant, including high-pressure and low-pressure units, amounts to 90,000 kw and approximately 38,000 hp for the turbine-driven rotary air compressors.

Engineering, design and construction supervision of the Emma plant have been carried on by the Department of Energy and associated departments of the State Mines.

Air Metering for Combustion Control

The air metering device described herein provides a means for indicating the flow of combustion air to boiler furnaces. It will give a reliable indication in clean air that will be closely proportional to the square of combustion air flow throughout the range of boiler operation. The device has an efficiency above 80 per cent, permitting an ample head for actuating a combustion pilot while causing a very small fan power loss.

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ONE of the important problems in the operation of large high-pressure boilers is that of getting a reasonably accurate measurement of the amount of combustion air being fed to the furnace. The head measurement should be ample for actuating a combustion control pilot and should remain proportional to the square of air flow throughout the entire range of boiler operation.

It is difficult to find a draft loss in the boiler system which is suitable for the measurement of gas flow that can be used for combustion control. Draft-loss measurements are not proportional to the square of gas flow because of many interfering variables, such as:

1. Changes in gas temperature with load.
2. Changes in percentage of CO_2.
3. Fouling of the tube bank that is selected for draft-loss measurement.
4. Fouling of draft-tube connections.
5. Difference in height of draft connections.
6. Changes in the distribution of gas flow in the section where the draft measurement is made. This change may be an inherent characteristic for the particular tube section, fouling, or the effect of changes in damper position. Automatic dampers controlling steam temperature usually do not have a definite setting for a given boiler output.
7. Time delay is another factor that causes improper control impulses when gas-flow measurements are used instead of air-flow measurements.

About the only benefit in measuring gas flow by draft loss is that no fan power is consumed in making the flow measurement. This saving cannot compensate for the many disadvantages of this type of measurement.

Our past experience with draft-loss impulses actuating combustion control pilots has been unsatisfactory for many or all of the reasons listed. A new method of combustion air measurement was required to solve the problem. Such a method would have to supply control impulses essentially proportional to the square of air flow throughout the range of operation and, because the method would impose an additional fan power loss, the friction loss of the measuring device should be kept to a minimum.

Model Tests

The orifice is not a very good solution to the problem of metering combustion air because it offers little guiding effect, its length being only the thickness of the orifice plate. For this reason one would not expect it to assist in maintaining a constant flow pattern throughout a wide range of boiler operation. Some type of restriction similar to a venturi tube would be an improvement in this respect. However, relatively long straight runs in forced-draft ducts are unusual, and it becomes necessary to adapt the venturi to the duct dimensions.

The air meter is such an adaptation designed to approximate a short venturi. It has a symmetrical streamlined form, and not only accelerates the main body of the air stream but in addition guides smaller high-

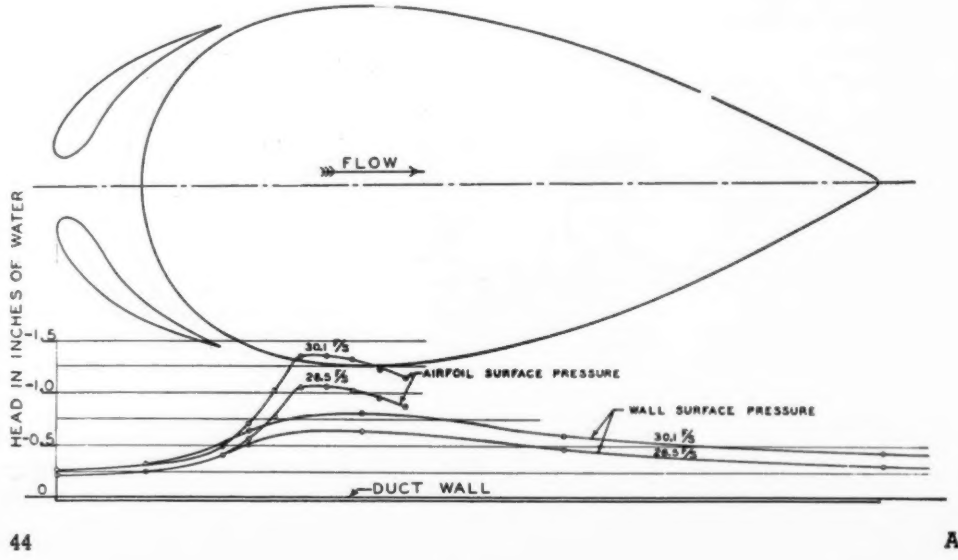


Fig. 1—Test of air meter showing head characteristics

velocity air streams along either side of the main airfoil. Normally the head measured by a venturi tube indicates the acceleration imparted to the main air stream, but in the case of the air meter this indication is approximately doubled due to the high-velocity layer that flows close to the outer surface of the airfoil.

The sketch in Fig. 1 is a plan view showing the proportions of the initial air meter design that was tested in a small wind tunnel at the University of Rochester in August 1947. This model was built to one-quarter scale. The main airfoil was fourteen inches long and twenty-two inches high, with two auxiliary airfoils. It was a modification of symmetrical sections developed in NACA tests, and similarly, the auxiliary airfoils and their arrangement were patterned after tests of slotted wing sections.

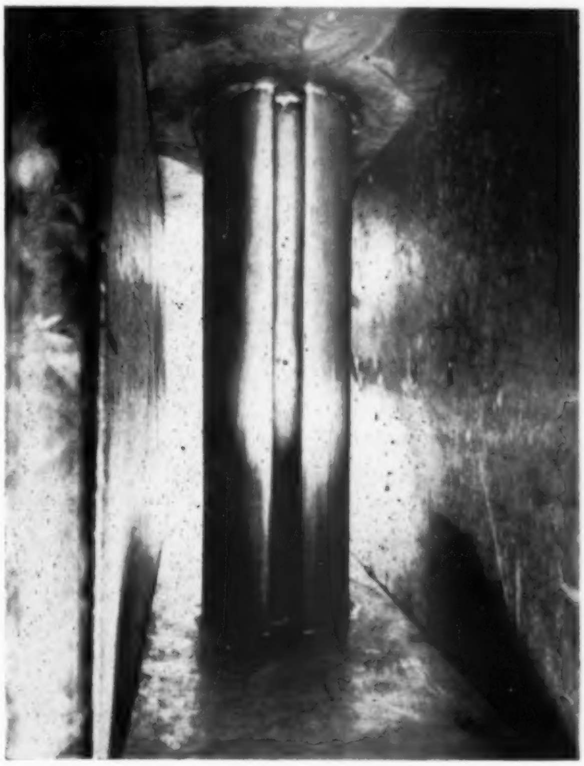


Fig. 2—Air meter mounted in wind tunnel in preparation for test

A photograph of the air meter mounted in the wind tunnel for test is shown in Fig. 2. This is a view looking downstream and shows the opening between the auxiliary airfoils and the Pitot connection in the nose of the main airfoil.

One object of the wind-tunnel tests was to determine the point along the surface of the main airfoil where the pressure dropped to the lowest point and the characteristic pressure variation in the vicinity of this point both upstream and downstream. The test was also useful in determining the increase in maximum pressure differential due to the use of the auxiliary airfoils. For the model this increase was found to be 70 per cent. The variation in pressure along the duct wall and surface of the main airfoil with respect to the impact pressure at the nose of the main airfoil is shown in the graph at the bottom of Fig. 1.

In designs developed from the model test for use in No 1 and No. 2 boilers at Russell Station, the maximum pressure differential of the air meter was 1.95 times the corresponding pressure differential that would occur if the auxiliary airfoils were omitted.

The friction loss along the section of the duct in which the model was mounted was 21 per cent of the air-meter differential. Recent tests of the air meter on No. 2 boiler show the friction loss to be 18 per cent of the differential. In these full-scale tests several impact tubes are placed immediately upstream and downstream from the meter, and the total head measurements were compared to determine the friction loss of the air-meter section.

Air-Meter Proportions

An outline sketch of the air meter giving critical dimensions is shown in Fig. 3. These dimensions are given in Table 1 as a per cent of length for three air-meter designs. The test air meter had somewhat greater thickness than later designs and was a little less efficient. It was originally considered necessary to confine the air meter to a straight length of air duct. This accounts for the greater thickness of the test air meter. Later, when the air meter was designed for No. 2 boiler, several feet of the tail section were constructed in a section of the duct that was rising at a 9-deg angle.

TABLE 1—AIR-METER DESIGN DIMENSIONS IN PER CENT OF LENGTH

Design Dimension	Test Meter	No. 1 Boiler Meter	No. 2 Boiler Meter
A	100	100	100
B	50	35	35
C	28.0	19.38	19.38
D	4.35	3.27	3.24
E	11.80	9.68	9.68
F	8.60	12.93	12.92
G	1.94	2.69	2.69
H	25.0	23.3	25.0

The coordinates of both the main and auxiliary airfoils in per cent of length are given in Table 2. These coordinates apply to the air meters used in No. 1 and No. 2 boilers. The slenderness ratio of the design can be changed by applying a factor to the coordinates given. Thus, if it were required to crowd the meter into a shorter section of duct this could be done by applying a factor greater than one to the coordinates. However, there would be some sacrifice in efficiency.

TABLE 2—AIR-METER FOIL COORDINATES

Main Airfoil Section		Auxiliary Airfoil Section	
Chord $x\%$	Chamber $\pm y\%$	Camber $+y\%$	Camber $-y\%$
0	0	−1.33	1.33
1.25	5.53	1.67	4.33
2.50	7.64	3.20	5.33
5.00	10.38	5.00	6.33
7.50	12.25	6.53	6.73
10	13.68	7.53	6.87
15	15.62	9.20	6.60
20	16.76	10.20	5.93
25	17.36	10.80	5.20
30	17.52	11.07	4.53
40	16.95	10.80	3.00
50	15.45	10.00	1.93
60	13.32	8.60	1.20
70	10.68	6.73	0.67
80	7.66	4.60	0.33
90	4.23	2.47	0.13
95	2.35	1.27	0.13
100	0.36	0.13	0.13

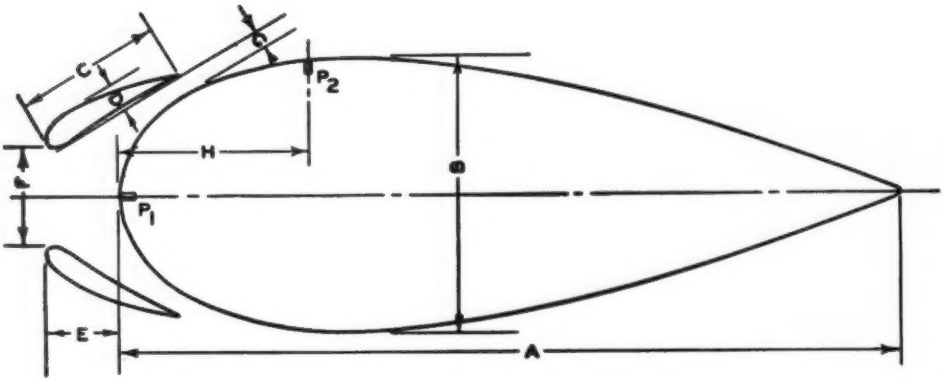


Fig. 3—Air-meter dimensions

Design of Gap

The gap between the wall of the duct and the sides of the main airfoil controls the velocities in the system. This gap is designed to give an acceleration that will increase the velocity head half the amount of the differential head required on the air meter. For instance, on No. 2 boiler with air flowing at a temperature of 560 F the maximum load velocity in the duct is 55.5 ft per sec. The main airfoil of the air meter constricts the duct accelerating the air to a velocity of 118 ft per sec. Thus the velocity head in the duct is increased from 0.35 in. to 1.59 in. of water, an increase of 1.24 in. This acceleration causes an air-meter differential of 2.45 in. of water.

Similarly, if a full-load differential of 1.50 in. of water would satisfy the requirement for combustion-control devices the gap could be increased, causing less acceleration and a correspondingly lower velocity head change of 0.75 in. Such a design would show an improvement in efficiency, but less ability to maintain similarity of flow pattern at reduced loads.

Vaning Ducts

A typical arrangement of the air meter in a duct is shown in Fig. 4. The right angle in the air duct must be vaned to assure a good distribution of air to the air meter. If the air coming to the vaned elbow has a well-distributed flow pattern, a set of seven vanes placed as shown will give a satisfactory air distribution into the air meter. The latter should be located as far as possible from the discharge of a set of vanes so that the velocities in the streams leaving the individual blades may have sufficient time to equalize.

In a duct 4 ft 9 in. wide by 6 ft high, seven vanes are spaced equally along the diagonal. A flat-plate aspect ratio of 4 is satisfactory. This is an unbent blade width of 18 in. The radius of the bend of half the flat plate width with a straight trailing section of one-third the width makes a satisfactory design. The remainder of the plate width is the straight leading section and is a little shorter than the trailing section.

The air is not evenly guided around the 90-deg turn but tends to pack against the guiding side of each vane. Higher velocities occur close to the vane and when the air is released by the vane, it does not follow the trailing edge but takes a lesser angle. For this reason it is necessary to turn the trailing edge of the vanes beyond the 90-deg position. Extensive tests of flow in large ducts indicate that the trailing edge of the vanes should be bent beyond 90 deg by the amounts in the following listing, the blades being numbered from the inner corner of the bend.

Blade No.	Vane Depression in Degrees
1	12
2	10
3	8
4	6
5	4
6	2
7	0

Air-Meter Details

A sketch showing details of the main airfoil is shown in Fig. 5. The air meter can be constructed of light metal, say $^1/_8$-in. sheet, if care is taken to prevent wrin-

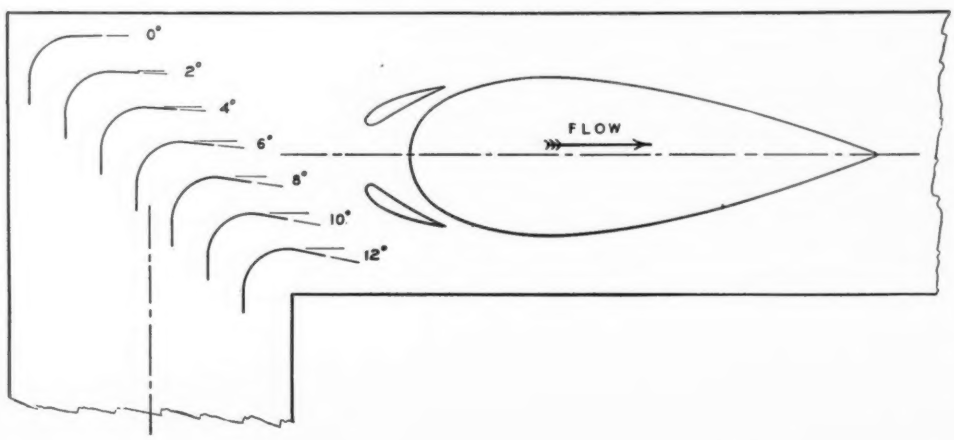


Fig. 4—Installation of air meter showing vanes for air distribution

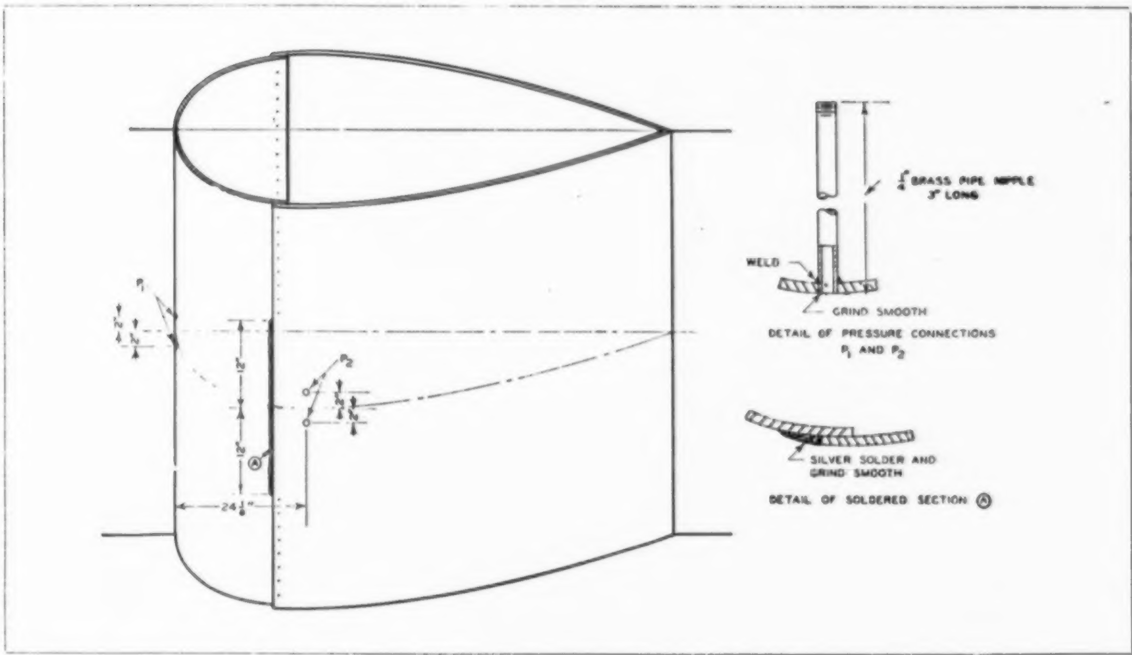


Fig. 5—Air-meter details

kling. If stiffeners are not used, the sheet forming the trailing section should be lapped outside the sheet forming the nose section. A small amount of leakage between the plates forming the air meter or at the top and bottom connection to the duct will not affect the performance. However, it is desirable to smooth out a portion of the lapped sheets in the vicinity of the pressure connections as shown in the sketch. If stiffeners are employed they can be used to back up a vertical butt joint between the nose and tail sheets of the air meter. The pressure connections should be ground smooth with the outer surface of the airfoil.

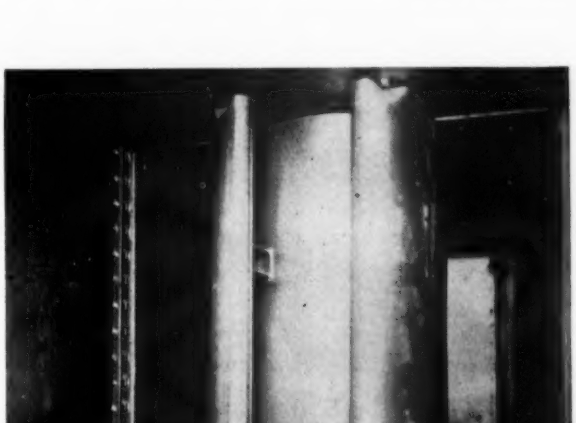


Fig. 6—Air meter showing auxiliary foil supports

An access door should be placed in the duct inside the airfoil section to permit inspection, cleaning, and changing pressure connections. Usually pressure connections are in pairs so that connections may be changed over in operation if one set fails due to plugging or leakage.

The air meter installation on No. 2 boiler required that it span an expansion joint in the air duct. For this reason it was necessary to support the auxiliary airfoils from the main section. The photograph, Fig 6, shows this support and the arrangement of the air meter in the duct.

Power Requirements

The power requirements for friction loss of the air meter and a comparison with requirements for an orifice plate are shown in Table 3.

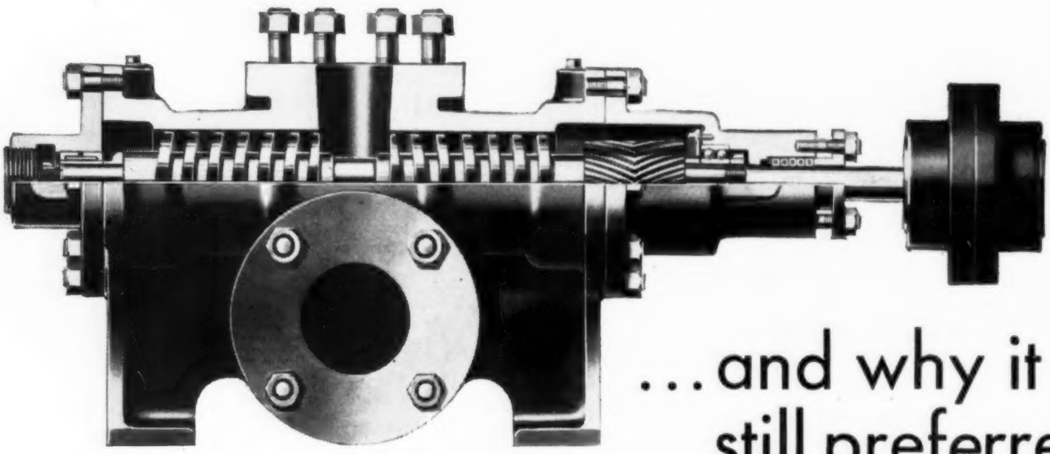
TABLE 3—COMPARISON OF POWER REQUIRED FOR MEASURING AIR BY THE METER AND BY AN ORIFICE

	Russell Station Unit No. 2	
Kilowatt load	70,000	46,600
Steam flow	470,000	300,000
Net plant heat rate	9,515	9,633
Coal flow, lb per hr	49,530	33,280
Total air flow, cfm (100 F)	132,970	95,300
Metered air from F. D. fans, cfm (100 F)	112,000	80,000
Useful control head, in. H_2O	2.10	1.07
Head loss with air meter, in. H_2O	0.37	0.19
Head loss with orifice, in. H_2O	0.84	0.43
Fan head with air meter, in. H_2O	11.20	5.72
Fan head with orifice, in. H_2O	11.67	5.96
Fan power with air meter, kw.	239.9	158.7
Fan power with orifice, kw.	250.0	165.3
Power saving using air meter, kw.	10.0	6.6
Efficiency of air meter, per cent	82	
Efficiency of orifice, per cent	60	

The air meter will accelerate air sufficient to multiply the velocity head of inflowing air seven times. It is recommended as an efficient measuring device that will give consistent control impulses over a wide range of boiler operation.

QUIMBY

...the Original Screw Pump



...and why it is still preferred

100% Anti-friction bearing equipped. Due to their rolling action and minimum lubricating requirements, anti-friction bearings maintain their original clearances without appreciable wear. No hydraulic shock or discharge pressure loads on the bearings because Warren-Quimby Screw Pumps are 100% balanced axially.

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Meeting Chemical Shortages in Water Treatment

By F. M. KEMMER
Cochrane Corporation

This article discusses steps that can be taken to alleviate existing shortages of certain chemicals, such as sulfuric acid, soda ash and various phosphate salts, sometimes without changing existing water-treatment plants. Relative cost figures are included.

ENCROACHMENT of war on our natural resources has finally awakened many to the realization that our mineral resources, unlike the produce of our fields and forests, cannot be replenished. Even should it be our good fortune to one day be able to relax our production of war material, the damage will have been done.

Sulfur, found in an almost pure state in nature, has long been a cheap raw material. Once considered almost inexhaustible, our sulfur reserves have diminished to the extent that export has been greatly restricted, and both here and abroad, alternate methods of producing sulfur and sulfuric acid are being sought. As a result, the price of sulfuric acid is rising and will continue to rise. Of more immediate importance, it is becoming increasingly difficult to obtain (1).*

Soda ash and caustic soda are also in short supply, due largely to a high rate of consumption and failure to keep supply abreast of increasing usage, because of the enormous expenditure required for soda ash production facilities and the shortage of electric power required to produce electrolytic caustic soda.

The world-wide shortage of fertilizers has pinched the consumer of phosphate reagents. Here, too, the present shortage is due to the time needed to expand production facilities and to the shortage of power and caustic soda required to produce sodium phosphate from phosphate rock.

There is little risk in predicting higher costs and increasing shortages of these materials in the future; there is much to gamble in hoping otherwise. Plans for substituting other reagents in water-treating plants for those in short supply should be considered now.

I—Sulfuric Acid

Sulfuric acid is used in water treatment for alkalinity reduction and pH control.

Alkalinity reduction is required for boiler feedwater, cooling water and for many process waters. In the first case, boiler feedwater alkalinity reduction is practiced to provide a minimum of carbonates in various forms so that these carbonates will be destroyed before they reach the boiler. Otherwise, they would decompose to liberate carbon dioxide with the steam, which, on redissolving in the condensate, would corrode the condensate return lines. The need for alkalinity reduction of cooling water is to prevent scale formation and, where wood cooling towers are in the circuit, to prevent delignification of the wood structure. The reduction of alkalinity in process water is related to the product. For example, soft drinks lose their acidic tang if prepared with alkaline waters; many operations in textile fabrication and finishing are adversely affected by alkaline waters; and there are many other examples too numerous to mention.

The control of pH is allied to alkalinity reduction, but in most instances it is practiced by a limited feed of sulfuric acid required to destroy calcium carbonate supersaturation, thus preventing pipe-line deposits.

Reduction of Alkalinity

Use of lime for alkalinity reduction may be substituted for sulfuric acid by installation of a sedimentation type softener. Lime for this purpose is most effective in waters containing appreciable hardness in addition to alkalinity. The comparison of hydrated lime to sulfuric acid is shown by the following reactions:

$$Ca(OH)_2 + Ca(HCO_3)_2 \rightarrow 2CaCO_3 \text{ (precipitated)} + 2H_2O \quad (1)$$

$$H_2SO_4 + Ca(HCO_3)_2 \rightarrow CaSO_4 + 2CO_2 \text{ (gas)} + 2H_2O \quad (2)$$

The water analyses of Figs. 1-a and 1-b show typical treatment of a hard well water by hydrated lime (in a cold process softener) and by sulfuric acid. Many plants having open recirculation-type cooling systems, heretofore reducing alkalinity by direct injection of sulfuric acid into the cooling tower basin, are now changing over to lime treatment to conserve scarce sulfuric acid. Fig. 2 shows a cold-process reactor installation using lime for alkalinity reduction.

In the case of alkaline raw waters having relatively low hardness, lime alone will not suffice to reduce the alkalinity, so that an additional reagent must be used to complete the treatment. Gypsum, calcium chloride or epsom salts may be used to supplement the lime feed as shown by the following reaction:

$$Ca(OH)_2 + 2NaHCO_3 \rightarrow Na_2CO_3 + CaCO_3 \text{ (ppt)} + 2H_2O \quad (3)$$

$$Na_2CO_3 + CaSO_4 \rightarrow Na_2SO_4 + CaCO_3 \text{ (ppt)} \quad (4)$$

Figs. 3-a and 3-b provide the analysis of a relatively soft, alkaline water and compare the treatment of this water in a cold-process reactor by hydrated lime and gypsum to treatment with sulfuric acid.

In the field of boiler feedwater treatment, the advent of the high-temperature styrene resin has meant the answer to the problem of alkalinity reduction for many

* Numbers apply to references at end of article.

Identification: A - Raw Water
B - Lime-softened water
C - Sulfuric Acid treated water, after decarbonation

	CONSTITUENT		Analysis in PPM as	A	B	C	D
CATIONS	Calcium	(Ca^{++})	$CaCO_3$	187	63	187	
	Magnesium	(Mg^{++})	$CaCO_3$	56	50	56	
	Sodium	(Na^{+})	$CaCO_3$	82	82	82	
	Hydrogen = FMA	(H^{+})	$CaCO_3$	0	0	0	
			$CaCO_3$	-	-	-	
TOTAL CATIONS			$CaCO_3$	325	195	325	
ANIONS	Bicarbonate	(HCO_3^{-})	$CaCO_3$	165	0	35	
	Carbonate	(CO_3^{--})	$CaCO_3$	0	35	0	
	Hydroxide	(OH^{-})	$CaCO_3$	0	0	0	
	Sulfate	(SO_4^{--})	$CaCO_3$	10	10	140	
	Chloride	(Cl^{-})	$CaCO_3$	150	150	150	
			$CaCO_3$				
TOTAL ANIONS			$CaCO_3$	325	195	325	
Total Hardness			$CaCO_3$	243	113	243	
Methyl Orange Alkalinity			$CaCO_3$	165	35	35	
Iron, Total			Fe	3	0	3	
Carbon Dioxide, Free			CO_2	15	0	10	
Silica			SiO_2	12	10	12	
Turbidity				20	5	20	
Total Dissolved Solids				453	240	450	
pH				7.4	9.6	7.1	
pH_S				-	-	--	
Langelier Index				-	-	-	

OPERATING COST

CHEMICALS	lbs. per 1000 gal	Chemical cost cents per lb.	Chemical cost—cents per 1000 gal
Hydrated Lime (93%)	1.14	1.0	1.14
Sulfuric acid (66°)	1.15	1.5	1.72

Fig. 1-a—Typical analysis with treatment of hard water by hydrated lime and sulfuric acid

plants. Where lime and soda ash formerly produced a feedwater having a hardness of 20 ppm and an alkalinity of 40–60 ppm, the elimination of soda ash and addition of sodium-zeolite softeners to existing equipment now produces an effluent of zero hardness and 20–25 ppm alkalinity. This will be discussed further in connection with substitutes for soda ash.

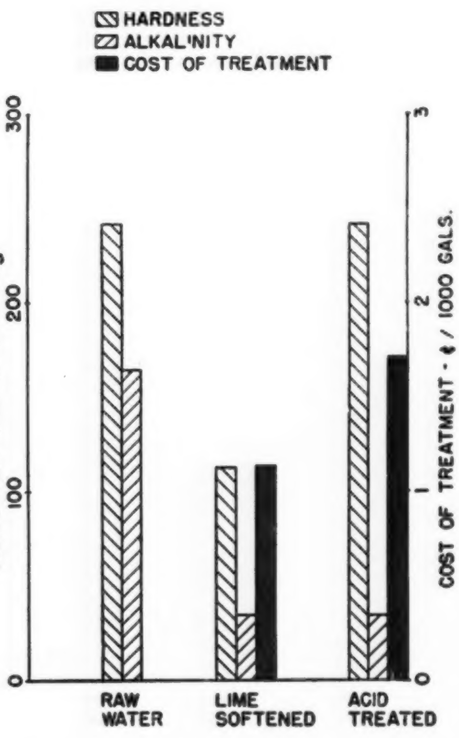

Fig. 1-b—Graphic representation of lime vs. sulfuric acid for alkalinity reduction

A new ion-exchange process for alkalinity reduction without the use of sulfuric acid has excited considerable interest and will undoubtedly gain a following despite a rather high equipment cost. In this process, a strong base anion exchanger, regenerated with salt, exchanges its chloride ion for the bicarbonate ion of the raw water. If the raw water is hard, a cation exchange resin can be mixed with the anion exchanger, and the salt will regenerate this exchanger to a sodium zeolite. The mixed-resin bed will thus simultaneously soften and de-alkalize the raw water (2). The reactions are as follows:

$$\text{Anion resin:}\quad Ca(HCO_3)_2 + 2R.Cl \rightarrow 2R.HCO_3 + CaCl_2 \qquad (5)$$

$$\text{Cation resin:}\quad CaCl_2 + Na_2Z \rightarrow CaZ + 2NaCl \qquad (6)$$

By this process, as shown by these reactions, calcium bicarbonate is converted to sodium chloride. The anion resin permits some slippage of alkalinity through the bed so that the effluent usually contains 5–15 ppm alkalinity. A comparison between this process, the sodium zeolite-plus-acid process and hydrogen zeolite-sodium zeolite is given in Figs. 4-a and 4-b.

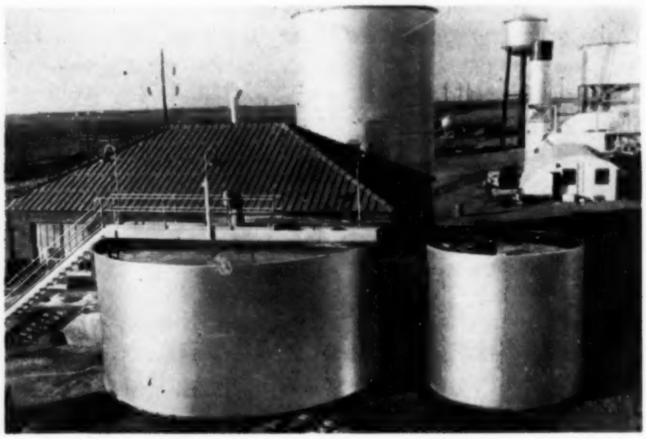

Fig. 2—Cold-process reactor using lime for alkalinity reduction

The simultaneous regeneration of the cation and anion resins with salt brine is shown in Reaction (7) as follows:

$$2NaCl + CaZ + 2R.HCO_3 \rightarrow Ca(HCO_3)_2 + Na_2Z + 2R.Cl \qquad (7)$$

The conversion of existing zeolite softeners to this process promises relief to plants where such softeners are presently regenerated with sulfuric acid or where sulfuric acid is fed as a supplementary treatment.

By-product hydrochloric acid at low cost is becoming increasingly available from chemical plants manufacturing chlorinated organic compounds. This will provide many water-treatment plants with a substitute for scarce sulfuric acid. However, the assay of such by-product acids must be carefully checked for harmful impurities before use can be decided upon.

The tabulation following shows the various chemicals available for alkalinity reduction and an index by which they may be compared on a cost basis. Even though sulfuric acid appears favorable on an economic basis, considering its rising cost and shortage and the hazard of handling, conversion to other reagents bears close

consideration. Note that the chloride anion exchange process appears rather unfavorable as a straight de-alkalizing process. However, when the fact is acknowledged that softening is accomplished by the same salt as is used for chloride exchange, this process becomes practical.

COMPARISON OF REAGENTS FOR ALKALINITY REDUCTION

Chemical Reagent	Cost, per Ton	Process	Treatment per 100 Gpm Alk Lb/1000 Gal	Treatment per 100 Gpm Alk ¢/1000 Gal	Index
Lime–93% $Ca(OH)_2$	\$20.00	Precipitation	0.67	0.67	1.0
H_2SO_4–66°Be	30.00	Direct Addition	0.85	1.28	1.9
Gypsum–$CaSO_4 \cdot 2H_2O$	24.00	Precipitation (1)	1.14	1.36	2.0
H_2SO_4–66°Be	30.00	Ion Exchange	1.46	2.20	3.3
Salt–NaCl	20.00	Anion Exchange (2)	2.65	2.65	4.0

NOTES: (1) Effective on carbonate alkalinity only; therefore, lime is required in addition to convert bicarbonates to carbonate.
(2) Cost position improves when simultaneously used for de-alkalization and softening.

REAGENTS FOR pH DEPRESSION

Even in cases where lime is presently being used for softening and alkalinity reduction, secondary acid feed is generally practiced for pH control. Particularly is this true of a reactor softening and de-alkalizing water for cooling towers. This is practiced to convert the carbonate alkalinity of the effluent, generally at a pH value of 9.2 to 9.8, to bicarbonate alkalinity at a pH of 6 to 8, since the high pH carbonate alkalinity tends to delignify the wood cooling towers, whereas the lower pH bicarbonate alkalinity in low concentrations will not. In this instance, recarbonation of the effluent can be substituted for sulfuric acid feed for pH correction. Recarbonation may be effected either by direct injection of CO_2 gas from cylinders or by a combustion process whereby fuel is burned to CO_2. The comparison of sulfuric acid to CO_2 for pH correction is shown by the following reactions:

$$CO_2 + H_2O + CaCO_3 \rightarrow Ca(HCO_3)_2 \qquad (8)$$

$$H_2SO_4 + 2CaCO_3 \rightarrow Ca(HCO_3)_2 + CaSO_4 \qquad (9)$$

The pH correction of a lime-treated water by these two processes is shown by the water analyses of Fig. 5.

Use of SO_2 produced by the burning of sulfur or by direct injection of the gas will have a similar effect. However, this solution is not consistent with the general fact that both sulfur and its by-products are in short supply.

It will be found that chlorine added to the main stream in a recirculation-type cooling system will introduce sufficient acidity to reduce the alkalinity of the added makeup, which is generally less than 3 per cent of the recycle flow. If other algaecides are being used, substitution of chlorine gas may eliminate the need for sulfuric acid for alkalinity reduction, as the chlorine will simultaneously sterilize and de-alkalize the cooling water.

II—Soda Ash

In the conditioning of water, soda ash is used principally to react with aluminum sulfate in coagulation plants and for reduction of noncarbonate hardness in softening plants. It is used less frequently for pH elevation of corrosive waters.

Identification: A - Raw Well Water; B - Lime-Gypsum Treated; C - Sulfuric acid treated, after decarbonation

	Constituent		Analysis in PPM as	A	B	C	D
CATIONS	Calcium	(Ca^{++})	$CaCO_3$	15	35	15	
	Magnesium	(Mg^{++})	$CaCO_3$	7	7	7	
	Sodium	(Na^+)	$CaCO_3$	282	282	282	
	Hydrogen = FMA	(H^+)	$CaCO_3$	0	0	0	
			$CaCO_3$	-	-	-	
TOTAL CATIONS			$CaCO_3$	304	324	304	
ANIONS	Bicarbonate	(HCO_3^-)	$CaCO_3$	275	0	35	
	Carbonate	(CO_3^{--})	$CaCO_3$	0	35	0	
	Hydroxide	(OH^-)	$CaCO_3$	0	0	0	
	Sulfate	(SO_4^{--})	$CaCO_3$	7	267	247	
	Chloride	(Cl^-)	$CaCO_3$	22	22	22	
			$CaCO_3$				
TOTAL ANIONS			$CaCO_3$	304	324	304	
Total Hardness			$CaCO_3$	22	42	22	
Methyl Orange Alkalinity			$CaCO_3$	275	35	35	
Iron, Total			Fe	0	0	0	
Carbon Dioxide, Free			CO_2	25	0	10	
Silica			SiO_2	45	45	45	
Turbidity				0	5	0	
Total Dissolved Solids				375	390	375	
pH				7.4	9.6	7.1	
pH_s				-	-	-	
Langelier Index				-	-	-	

OPERATING COST

Chemicals	lbs. per 1000 gal	Chemical cost cents per lb.	Chemical cost—cents per 1000 gal
1. Hydrated Lime (93%)	1.83	1.0	1.83) 6.2
Gypsum	3.71	1.2	4.47)
2. Sulfuric acid (66°)	2.12	1.5	3.18

Fig. 3-a—Analysis of relatively soft, alkaline water with lime-gypsum treatment

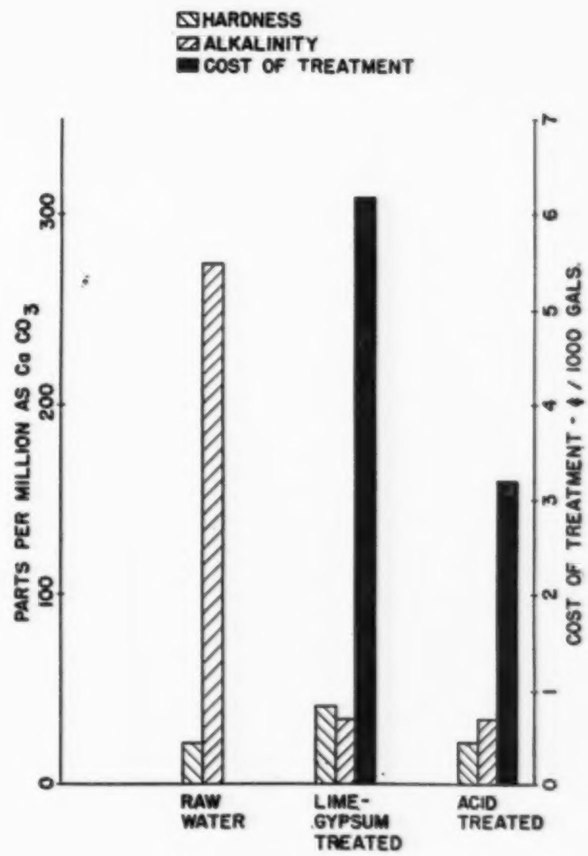

Fig. 3-b—Lime-gypsum vs. acid treatments compared graphically

Identification: A - Raw Water
B - De-Alkalized by Cation-Anion Exchange, salt cycle
C - Sodium zeolite plus acid, after decarbonation
D - H_2Z-Na_2Z, after decarbonation

	Constituent		Analysis in PPM as	A	B	C	D
Cations	Calcium	(Ca^{++})	$CaCO_3$	75	2	2	2
	Magnesium	(Mg^{++})	$CaCO_3$	20	1	1	1
	Sodium	(Na^{+})	$CaCO_3$	18	110	110	40
	Hydrogen = FMA	(H^{+})	$CaCO_3$	0	0	0	0
			$CaCO_3$	-	-	-	-
Total Cations			$CaCO_3$	113	113	113	43
Anions	Bicarbonate	(HCO_3^{-})	$CaCO_3$	85	15	15	15
	Carbonate	(CO_3^{--})	$CaCO_3$	0	0	0	0
	Hydroxide	(OH^{-})	$CaCO_3$	0	0	0	0
	Sulfate	(SO_4^{--})	$CaCO_3$	18	0	88	18
	Chloride	(Cl^{-})	$CaCO_3$	10	98	10	10
			$CaCO_3$				
Total Anions			$CaCO_3$	113	113	113	43
Total Hardness			$CaCO_3$	95	3	3	3
Methyl Orange Alkalinity			$CaCO_3$	85	15	15	15
Iron, Total			Fe	0	0	0	0
Carbon Dioxide, Free			CO_2	6	6	5	5
Silica			SiO_2	5	5	5	5
Turbidity				0	0	0	0
Total Dissolved Solids				125	145	125	50
pH				7.6	7.1	7.1	7.1
pH_S				-	-	-	-
Langelier Index				-	-	-	-

Operating Cost

Chemicals	lbs per 1000 gal B	lbs per 1000 gal C	lbs per 1000 gal D	* Chemical cost cents per lb	Chemical cost—cents per 1000 gal B	Chemical cost—cents per 1000 gal C	Chemical cost—cents per 1000 gal D
Salt	2.7	2.5	0.9	1.0	2.7	2.5	0.9
Acid	-	0.6	1.1	1.5	-	0.9	1.6
Total					2.7	3.4	2.5

Fig. 4-a—Analyses with sodium zeolite-plus acid and with hydrogen zeolite-sodium zeolite treatment

Substitute Alkali for Coagulation

In coagulation work, lime can be substituted for soda ash to advantage. Reaction with aluminum sulfate by these two reagents is shown by the following reactions:

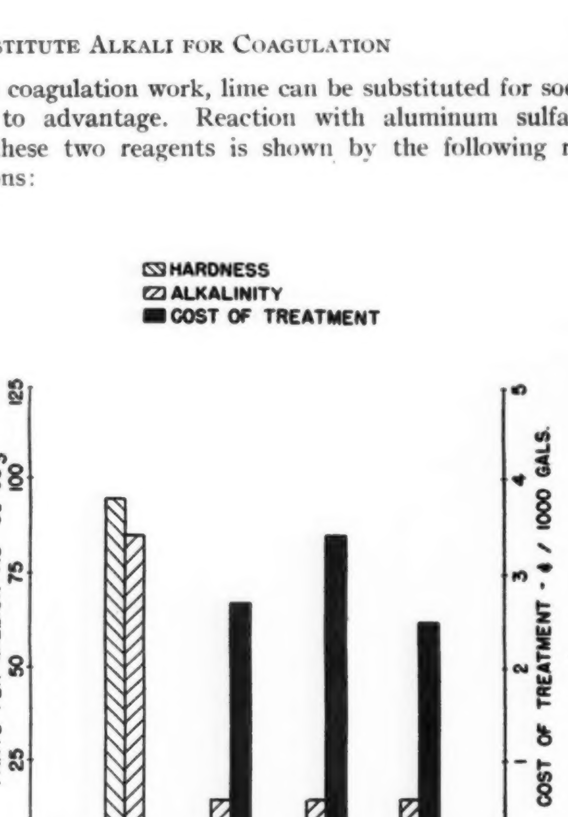

Fig. 4-b—Alkalinity and hardness reduction by chloride anion exchange vs. sodium zeolite-plus acid and hydrogen-sodium zeolite

$$2Al_2(SO_4)_3 + 6Ca(OH)_2 \rightarrow 4Al(OH)_3 + 6CaSO_4 \qquad (10)$$

$$2Al_2(SO_4)_3 + 9Na_2CO_3 + 9H_2O \rightarrow 4Al(OH)_3 + 6Na_2SO_4 + 6NaHCO_3 + 3CO_2 \qquad (11)$$

Note that for the same amount of alum floc formed, only two-thirds as much lime is needed as soda ash. (The soda-ash requirement was calculated to produce a pH of approximately 6.8.) Lime increases the noncarbonate hardness, whereas soda ash increases the alkalinity and carbon dioxide of the treated water. The total electrolyte content of the soda-ash coagulation is 50 per cent more than the by-product electrolyte content of lime treatment, so that subsequent water-conditioning processes might be penalized by soda ash treatment—particularly if demineralization is involved—and blowoff will be increased from cooling towers or boilers over that resulting from lime treatment. Incidentally, even caustic soda would be a fit substitute for soda ash from the standpoint of by-product electrolytes (although generally not from the availability angle) as shown by the following reaction:

$$2Al_2(SO_4)_3 + 12NaOH \rightarrow 4Al(OH)_3 + 6Na_2SO_4 \qquad (12)$$

In the coagulation of iron salts—copperas, ferric sulfate and ferric chloride—the use of lime is even more favorable, as a pH value higher than can be economically attained with soda ash is usually required.

Reduction of Permanent Hardness

Use of soda ash for reduction of noncarbonate hardness is an almost traditional process in the treatment of boiler feedwater. It is used, even before lime, for external treatment by addition to the water storage space below the trays of an open heater, rough filtration being accomplished by a fill of coke or excelsior in the bottom of the heater. The process is as follows:

$$CaSO_4 + Na_2CO_3 \rightarrow CaCO_3\,(ppt) + Na_2SO_4 \qquad (13)$$

Existing lime-soda softening plants, wishing to continue present treating methods and satisfied with the type of water produced, can overcome the soda-ash shortage by producing an excess of sodium alkalinity in the raw water supply through partial sodium-zeolite softening. A portion of the hard raw water is shunted through a sodium-zeolite unit, recombining with the main water stream ahead of the sedimentation tank. The analysis of a typical hard raw water presently being softened with lime and soda ash is shown in Fig. 6. The second column (B) of the tabulation shows the analysis of the portion of this water shunted through a sodium-zeolite softener; and the third column (C) shows the blended, recombined water ahead of the sedimentation tank. This blended water, treated with lime alone, will produce the same effluent as the raw water now being treated with lime and soda ash, as shown in column D.

Calculation of the portion of the raw water to be bypassed around the sodium-zeolite softener is given as follows:

$$RW = \frac{(A - 30)}{H} \times 100\%$$

where

RW = per cent raw water bypassing sodium-zeolite softener
A = alkalinity of raw water
H = hardness of raw water

The process described above produces sodium alkalinity in the water in excess of the hardness so that soda ash is unnecessary to supplement the lime treatment. This process was reported as having been used during the last war (3).

This same result can be accomplished by substituting caustic soda for soda ash and lime whenever the calculated lime-soda ash requirements are such that the lime is more than 75 per cent of the soda ash. Of course, caustic soda is also in short supply generally; but there are undoubtedly cases where soda ash is unobtainable and caustic soda may be had. This condition prevails in the Northwest, remote from the soda ash producer, but near a source of electrolytic caustic soda. The economics indicate that this is a practical substitution, if the caustic soda is available, since the caustic soda will at the same time eliminate soda ash and reduce the lime requirements. This is indicated as follows:

$$\underset{80}{Ca(OH)_2} + \underset{106}{Na_2CO_3} \rightarrow CaCO_3 + \underset{80}{2NaOH} \qquad (14)$$

Thus, 80 parts of caustic soda at about 3.5 cents per lb will replace 106 parts of soda ash at 2.0 cents per lb and 80 parts of 95 per cent hydrated lime at 1.0 cent per lb.

The boiler itself can be tapped as a source of caustic soda to accomplish this same result. If the boiler water contains 500 ppm caustic soda, for example, recirculation of 5 per cent from the blowdown line to the sedimentation tank will provide caustic equivalent to the excess soda ash normally carried in the majority of hot-process lime-soda softeners. The cost of caustic soda from this source is the degradation of heat and loss of some available power; nevertheless, the process of boiler water recirculation will surely provide relief to some plants faced with a curtailed supply of soda ash.

The Hot Lime-Zeolite Process

By simultaneously eliminating soda ash from hot-process softening and making possible low alkalinity effluent, the combination of a lime softener followed by a high-temperature sodium-zeolite unit is gaining increasing popularity. Not only are many new plants being designed around this system, but more pertinent to the problem of meeting the soda-ash shortage, existing hot-process softeners are being converted to hot lime-zeolite.

The presence of noncarbonate hardness, such as calcium sulfate, has heretofore imposed a burden on the hot-process softener by requiring soda ash for its removal. When the water supply is variable, this requires careful attention to both the lime feed and the soda-ash feed to compensate for changes in the chemical character of the supply.

The lime-zeolite process transforms the presence of noncarbonate hardness in the supply from a liability to an asset. This is because the noncarbonate hardness, in the absence of soda ash, depresses the carbonate alkalinity. This has been termed the "excess calcium" method of treatment (4).

Like other slightly soluble compounds, calcium carbonate has a solubility product, expressed mathematically as:

$$Ca^{++} \times CO_3^{--} = K \text{ (a constant)}$$

Identification: A - Lime softened water; B - Carbonated Lime - Softened water; C - Acidified Lime-Softened Water

	Constituent		Analysis in PPM as	A	B	C	D
Cations	Calcium	(Ca^{++})	$CaCO_3$	63	63	63	
	Magnesium	(Mg^{++})	$CaCO_3$	50	50	50	
	Sodium	(Na^{+})	$CaCO_3$	82	82	82	
	Hydrogen = FMA	(H^{+})	$CaCO_3$	0	0	0	
			$CaCO_3$	-	-	-	
Total Cations			$CaCO_3$	195	195	195	
Anions	Bicarbonate	(HCO_3^{-})	$CaCO_3$	0	35	17.5	
	Carbonate	(CO_3^{--})	$CaCO_3$	35	0	0	
	Hydroxide	(OH^{-})	$CaCO_3$	0	0	0	
	Sulfate	(SO_4^{--})	$CaCO_3$	10	10	27.5	
	Chloride	(Cl^{-})	$CaCO_3$	150	150	150	
			$CaCO_3$				
Total Anions			$CaCO_3$	195	195	195	
Total Hardness			$CaCO_3$	113	113	113	
Methyl Orange Alkalinity			$CaCO_3$	35	35	17.5	
Iron, Total			Fe	0	0	0	
Carbon Dioxide, Free			CO_2	0	0	0	
Silica			SiO_2	10	10	10	
Turbidity				5	5	5	
Total Dissolved Solids				240	240	240	
pH				9.6	8.3	8.3	
pH_s				-	-	-	
Langelier Index				-	-	-	

Operating Cost

Chemicals	lb per 1000 gal	Chemical cost cents per lb	Chemical cost—cents per 1000 gal
Carbon Dioxide	0.13	6 (1) 2¢ Kw Hr (2)	0.78 (1) 0.04 (2)
Sulfuric Acid	0.15	1.5	0.23

Note: (1) CO_2 in cylinders (2) CO_2 pumped from stack

Fig. 5—Analyses of pH correction of a lime-softened water by carbonated lime and by acidified lime

With soda ash treatment, the calcium solubility in this equation is depressed by the introduction of the carbonate ion present in the soda ash; conversely, the

Identification: A - Raw Water; B - Sodium Zeolite Softened Water; C - Blended raw water and sodium zeolite water; D - Blended water after lime softening

	Constituent		Analysis in PPM as	A	B	C	D	E
Cations	Calcium	(Ca^{++})	$CaCO_3$	270	2	217	18	
	Magnesium	(Mg^{++})	$CaCO_3$	140	1	112	2	
	Sodium	(Na^{+})	$CaCO_3$	70	477	151	151	
	Hydrogen = FMA	(H^{+})	$CaCO_3$	0	0	0	0	
			$CaCO_3$	-	-	-	-	
Total Cations			$CaCO_3$	480	480	480	171	
Anions	Bicarbonate	(HCO_3^{-})	$CaCO_3$	360	360	360	0	
	Carbonate	(CO_3^{--})	$CaCO_3$	0	0	0	50	
	Hydroxide	(OH^{-})	$CaCO_3$	0	0	0	1	
	Sulfate	(SO_4^{--})	$CaCO_3$	85	85	85	85	
	Chloride	(Cl^{-})	$CaCO_3$	35	35	35	35	
			$CaCO_3$					
Total Anions			$CaCO_3$	480	480	480	171	
Total Hardness			$CaCO_3$	410	3	329	20	
Methyl Orange Alkalinity			$CaCO_3$	360	360	360	51	
Iron, Total			Fe	2	0	2	0	
Carbon Dioxide, Free			CO_2	30	30	30	0	
Silica			SiO_2	24	24	24	2	
Turbidity				0	0	0	0	
Total Dissolved Solids				570	595	575	195	
pH				7.5	7.5	7.5	9.8	
pH_s				-	-	-	-	
Langelier Index				-	-	-	-	

Operating Cost

Chemicals	lb per 1000 gal	Chemical cost cents per lb	Chemical cost—cents per 1000 gallons: Zeolite-Lime	Lime-Soda
Lime (93% $Ca(OH)_2$)	3.33	1.0	3.33	3.33
Salt	1.44	1.0	1.44	-
Soda ash	0.72	2.0	-	1.44
Total			4.77	4.77

Fig. 6—Analysis of typical hard raw water softened with lime and soda ash

carbonate ion can be depressed by the presence of excess calcium in the raw water. Fig. 7 illustrates this principle.

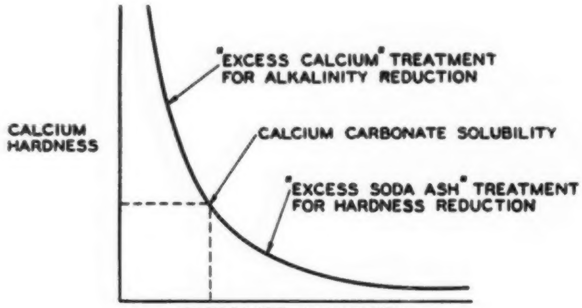

Fig. 7—Excess soda vs. excess calcium treatment

Consequently, not only does the hot lime-zeolite process eliminate the problem of soda-ash shortages, but it actually produces a superior water from the standpoint of residual carbonate alkalinity. The excess calcium hardness is economically removed by salt-regenerated sodium zeolite following the sedimentation tank.

Fig. 8 illustrates the comparative results obtained in treating a water containing noncarbonate hardness by lime-soda and lime-zeolite at high temperature.

If the suspended matter leaving a hot lime softener is not filtered from the effluent before the water enters the zeolite softener, this suspended matter—chiefly calcium carbonate—will re-dissolve to some extent in the zeolite bed, increasing the alkalinity and thus defeating one of the chief advantages of this system (5). The re-dissolved calcium carbonate will, of course, also consume a part of the softening capacity of the zeolite bed and thereby increase the operating cost.

III—Sodium Phosphate

Since the pioneer work of R. E. Hall and his co-workers (6), phosphate treatment of boiler waters has become standard power plant practice. The phosphate reagents were originally fed directly into the boiler drum. Subsequently, disodium and trisodium phosphates were used as external softening reagents, first in the treatment of relatively soft waters (either natural waters or supplies partially softened by the cold lime-soda process) in a single stage and later as a second-stage treatment following a hot lime-soda first stage. The external phosphate treatment reduced the suspended solids in the boiler below that produced by internal treatment alone, thus facilitating progress in the trend toward higher pressure boiler operation. A later technique made it possible to utilize phosphoric acid—the most economical of the phosphate reagents on the basis of available PO_4 — for simultaneous softening and alkalinity reduction in a hot-process sedimentation tank (7).

Since it is necessary to maintain a slight PO_4 residual in the boiler saline, the shortage of phosphate reagents is a serious problem. There is no substitute for these reagents, but the shortage may be met by reducing the required dosage to stretch the available supply.

The effluent hardness of most hot-process lime-soda softeners is in the range of 15–25 ppm as $CaCO_3$, requiring approximately 0.20–0.25 lb per 1000 gallons of anhydrous disodium phosphate with either external or internal treatment. On the other hand, the effluent of a sodium-zeolite softener averages only 1–2 ppm as $CaCO_3$ in hardness, and the phosphate dosage is only 0.05 lb per 1000 gallons or less.

Consequently, the hot lime-zeolite softening system previously discussed as a means of eliminating soda ash, will also result in a reduction of supplementary phosphate to only 20–25 per cent of the dosage presently used following a hot-process lime-soda softener. Existing lime-soda plants need only add sodium-zeolite units to their present system in order to meet the phosphate shortage.

Addition of sodium zeolite to present facilities will also afford an economy, since the salt used for hardness reduction is considerably less expensive than the phosphate otherwise required.

Identification: A = Raw water
B = After Lime-soda ash treatment, hot
C = After lime-zeolite treatment, hot

	Constituent		Analysis in PPM as	A	B	C	D
Cations	Calcium	(Ca^{++})	$CaCO_3$	183	18	1	
	Magnesium	(Mg^{++})	$CaCO_3$	74	2	1	
	Sodium	(Na^{+})	$CaCO_3$	65	138	131	
	Hydrogen = FMA	(H^{+})	$CaCO_3$	0	0	0	
			$CaCO_3$	-	-	-	
TOTAL CATIONS			$CaCO_3$	322	158	133	
Anions	Bicarbonate	(HCO_3^{-})	$CaCO_3$	210	0	0	
	Carbonate	(CO_3^{--})	$CaCO_3$	0	50	25	
	Hydroxide	(OH^{-})	$CaCO_3$	0	0	0	
	Sulfate	(SO_4^{--})	$CaCO_3$	86	86	86	
	Chloride	(Cl^{-})	$CaCO_3$	26	22	22	
			$CaCO_3$				
TOTAL ANIONS			$CaCO_3$	322	158	133	
Total Hardness			$CaCO_3$	257	20	2	
Methyl Orange Alkalinity			$CaCO_3$	210	50	25	
Iron, Total			Fe	0	0	0	
Carbon Dioxide, Free			CO_2	13	0	0	
Silica			SiO_2	24	2	2	
Turbidity				35	0	0	
Total Dissolved Solids				375	175	150	
pH				7.7	9.8	9.8	
pH_S				-	-	-	
Langelier Index				-	-	-	

OPERATING COST

Chemicals	lbs. per 1000 gal A	lbs. per 1000 gal B	Chemical cost cents per lb	Chemical cost—cents per 1000 gal A	Chemical cost—cents per 1000 gal B
Lime (93% $Ca(OH)_2$)	1.90	1.90	1.0	1.90	1.90
Soda ash	0.65	-	2.0	1.30	-
Salt	-	1.19	1.0	-	1.19
				3.20	3.09

Fig. 8—Illustrates treatment of water containing noncarbonate hardness by lime-soda and lime-zeolite at high temperature

The glassy phosphates are widely used in treatment of process waters, particularly where the water is employed in once-through or recirculation types of cooling systems. A recent article has given as typical concentrations of meta-phosphate 2–3 ppm for prevention of deposits and 10–20 ppm for prevention of corrosion (8). In the open-recirculation type cooling system, elimination of phosphate is not generally advisable since susceptibility to corrosion is inherent in this system because the water is constantly being aerated by the cooling tower or spray pond. Even when operating with a positive Langelier Index to form an eggshell deposit to protect the heat-

exchange surfaces against corrosion, most industrial plants operate heat-exchange equipment at a wide range of temperature so that a single water treatment may provide a positive index in some heat-exchange units and a negative index in others. Only in the case of a power plant condenser cooling system might it be possible to operate cold lime-softening equipment to provide an effluent which will stabilize the system against occurrence of either corrosion or scaling in the absence of phosphate residual.

In the case of the once-through system, however, phosphate requirements may be reduced or eliminated by deaeration of the cooling water at its source. If the raw water is hard and contains carbon dioxide, elimination of the carbon dioxide with oxygen in the cold water deaerator may result in the effluent's having a positive Langelier Index. In this case a few parts per million of poly-phosphate must still be fed or the water must be partially softened to destroy the $CaCO_3$ supersaturation. However, the elimination of oxygen by deaeration will provide relief by reducing the normal poly-phosphate residual from 10–20 ppm to 2–3 ppm, if the Langelier Index is high in the deaerated effluent and possibly to zero if the Langelier Index is close to zero.

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Lignite to be Burned as Fuel for Aluminum Production

Announcement has been made by the Aluminum Company of America of plans for building a new aluminum smelting plant to use lignite for fuel. The exact location has not been decided upon but will be close to the Milam County lignite deposits about 60 miles south of Waco, Texas. When completed the plant will have a production capacity of 85,000 tons of aluminum annually.

The existence of large deposits of lignite in the Milam County area has been known for many years. The feasibility of using processed Texas lignite as a major fuel source resulted only recently due to new developments in fuel technology.

The large amounts of electricity required by the new plant will be generated by steam-driven equipment using this processed lignite as fuel. The power generating facilities will be built and operated for the Aluminum Company of America by the Texas Power & Light Company. Although detailed negotiations have not been completed, the arrangement will provide for an interchange of power between the ALCOA-owned power plant and Texas Power & Light to insure a firm power supply for the aluminum smelter.

The location of the new plant at a Milam County site has two advantages. Reserves of lignite are available to supply fuel needs for many years, and the Texas Power & Light Co. is in a position to supply interim power sufficient for partial operation of the smelter before completion of the generating plant.

Lignite has long had possibilities as a major source of low-cost power. The present development is being made possible by the Texas Power & Light Co., which sponsored an extensive research and experimental program, and by the Bureau of Mines of the Department of Interior, which carried out the project in a pilot plant at Denver, Colorado.

Engineering surveys show that lignite deposits in Milam County exist to a depth of several hundred feet on the site of a prehistoric river bed. The fuel can be extracted by strip or by slope mining.

It is expected that the lignite-fueled plant should enable the new Milam County operation to produce competitively with other plants of the same company which are dependent for electric power upon hydro and gas-engine sources.

Facts and Figures

Soot is composed of agglomerated smoke particles.

West Virginia is the state which produces the greatest tonnage of bituminous coal.

The world's largest tanker is capable of carrying 258,000 bbl of oil.

Approximately one third of Japan's power generating facilities are thermal-electric and two thirds hydro.

More than 800,000 ingot tons of stainless steel were produced in this country last year.

A surface temperature above 700 F is capable of quickly igniting most combustible materials.

The fusion temperature of fuel oil ash usually runs considerably under that of most coals.

The average worker in manufacturing industries in this country employs about 13,000 kwhr per year.

The first commercial natural gas well in the United States dates back to 1821 at Fredonia, N. Y.

According to Appalachian Coals, the present above-ground stocks of bituminous coal are approximately 72 million tons.

Nineteen American oil companies, operating abroad, have been requested by the U. S. Government to keep the supply of oil flowing to friendly nations.

The first of six of the world's largest pumps was officially put in service on June 14 at the Grand Coulee Dam. Each of these Byron Jackson pumps is capable of handling 720,000 gpm and is driven by a 65,000-hp motor.

According to the Bureau of Mines, more than 120 million tons of coal has been saved from destruction during the last three years as a result of its program of controlling fires in inactive coal deposits throughout the United States. The cost has been less than a cent a ton.

Large quantities of aluminum powder, normally employed in making aluminum paint, such as is sometimes applied to steel stacks, are now being diverted to the manufacture of incendiary bombs, star shells and other explosives.

The Defense Solid Fuels Administration estimates that TVA, because of its present large steam plant construction program, will require approximately 8 million tons of coal in 1954, as compared with its present annual consumption of 900,000 tons.

Shipments of river coal, largely dredged from the Susquehanna and Schuylkill Rivers, averaged for the last ten years well over a million tons annually; but, according to Anthracite Institute, dredge production is declining and is contributing diminishing proportions of total available supply of barley and smaller sizes.

Advisory Committee Reports on Atomic Power

THE Advisory Committee on cooperation between the electric power industry and the Atomic Energy Commission has submitted a report to the latter containing recommendations for continued studies in areas of mutual interest. This preliminary committee, under the chairmanship of Philip Sporn, president of American Gas & Electric Service Corp., also included E. W. Morehouse of General Public Utilities Corp., and Walton Seymour, formerly of the Interior Department and at present adviser on power problems to the Economic Cooperation Administration.

In making the survey the Committee not only held numerous conferences with the Atomic Energy Commission, in which it was given access to necessary information, but it also visited atomic energy installations at the Argonne, Oak Ridge and Brookhaven National Laboratories, the Hanford Works, the Knolls Atomic Power Laboratory at Schenectady and the Bettis Field Laboratory at Pittsburgh. Excerpts from the report follow:

The special interest of the electric power industry derives from the prospect of utilizing atomic power for ordinary central station purposes. If this prospect becomes a commercial reality, then, aside from weapon production, the power systems of the country could be the largest potential users of nuclear reactors, just as they are today the largest users of fuel-fired steam boilers. Similarly, they could become the largest potential users of nuclear fuel.

Whether and when atomic power becomes commercially feasible depends upon the Commission's nuclear reactor program which, except for the piles producing plutonium for bombs, is still in the research and pilot plant stage. While none of the reactors which form part of the present AEC program have been designed primarily with an eye to industrial power production, they will give impetus to the ultimate use of nuclear energy for such purposes. The AEC-Westinghouse land prototype for submarine propulsion is well under construction at the Reactor Testing Station in Idaho; and the companion project, for which General Electric is contractor, will soon be under construction.

Also, the homogeneous reactor at Oak Ridge promises to illuminate several key problems relevant to the eventual development of a practical power reactor.

While the prospect of nuclear breeding has the most dramatic appeal, there are other possibilities such as combining production of plutonium for weapons with utilization of by-product heat energy.

No valid judgment can yet be made as to whether and on what scale reactors will ultimately contribute to our energy resources. Nevertheless, prospects for an important new source of power within the next decades are robust enough to warrant a strong present and continuing interest on the part of the electric power industry. This is not because conventional methods of producing power are unsatisfactory, but because our natural endowment of large amounts of cheap coal, oil and natural gas, and our continuous developments and techniques of large-scale power production units have set a difficult mark for any new source of power to meet. However, the same conditions which helped bring the art of conventional power production to its present stage also foster an interest in a new source of heat energy potentially capable of providing a further advance in the art.

Electric generation in the United States has been predominantly dependent upon steam and will certainly continue to be heavily dependent upon heat energy. Hydro power, although substantial, can provide only a part of our rapidly growing requirements because the remaining undeveloped water-power sites are limited. The electric industry today requires in the operation of its steam plants fuel equivalent to about 100 million tons of coal annually, which is roughly about one sixth of the country's coal consumption.

The industry should be strongly attracted by any prospect for the production of heat energy which might bring about a material lowering in cost of steam power production, but no one should expect that commercially feasible atomic power would mean radical reductions in power costs. If nuclear reactors can produce heat energy for power plants, that energy would replace the fuel element in conventional electric generation, but with some increase in capital costs. There is little, if any, prospect that the overall cost reduction could be revolutionary, but the results could be significant, especially for certain industrial operations, such as reduction of magnesium and aluminum, the refining of copper or the production of cement, chlorine and caustic soda where electric power represents a substantial part of the cost of the finished product.

Thermal Efficiency of 38 Pecent

In order to make wise current plans and prudent investments for the future, the electric industry must at all times keep abreast of developments relating to power production and what they foreshadow, so that costs may be kept down and service improved. In the field of conventional power production it is able to give effect to these interests through working relationships with the manufacturers of power equipment, producers of fuel and with institutions where research and development are being carried on. For example, today a 38 per cent thermal efficiency is achieved in the best of the new power plants, whereas a few years ago the efficiency was only 13 to 15 per cent. A major contributing factor in this advance has been the practice of members of the electric power

industry, in contrast to most other industries, of sharing technical and operating experience fully and freely with one another.

Areas of Mutual Interest

In the collaboration between electric industry technicians and the manufacturers of power equipment, operating experience of the former has frequently been drawn upon in solving certain problems. It is suggested that a similar joint approach to the Commission's problems would be welcome and useful. There is, however, a broader and more important area of mutual interest than specific technical problems. As the Commission's reactor program proceeds, it will become increasingly necessary to make realistic appraisals of the potentialities of reactor projects as parts of electric power systems. These analyses will require not only the talents of the physicists, chemical and mechanical engineers, but also those of the system planning engineers, transmission engineers and utility management experts. The issues to be dealt with involve the balancing of all the many factors entering into final cost in an operation that involves numerous variables.

Continuing Cooperation

The AEC Industrial Advisory Group's report of two years ago placed primary emphasis on increasing industry's knowledge of atomic energy. It would appear that events are beginning to bear out this theory, an example being the recently approved project for reactor studies by the Detroit Edison, the Dow Chemical Companies and the Monsanto Chemical Company.

In order that the power industry may attain a part in atomic energy comparable to the useful rôle it has had in development of conventional power equipment, it must first become educated in the subject. One opportunity along this line is afforded by the Commission's Oak Ridge School of Reactor Technology, which has just announced its 1951–1952 session. Here qualified trainees from industrial firms can secure a substantial background in reactor technology and allied subjects. It is hoped and expected that, as time goes on, personnel from the electric industry will seek admission to this school and that the school will emphasize those features of training which would make it worth while for such personnel to attend.

Another valuable type of educational experience is that to be secured by power industry technicians as a by-product of assignments to assist the Commission with certain specific technological problems. As they return to their respective companies, these men (as well as those who attend the Oak Ridge School) would form a reservoir of informed personnel.

This leads to the suggestion that a permanent committee be set up, its first assignment being to provide organized power industry assistance to the various Commission projects in identifying the places where the industry personnel could be helpful. Such a committee's rôle should be conceived in quite simple terms as it is

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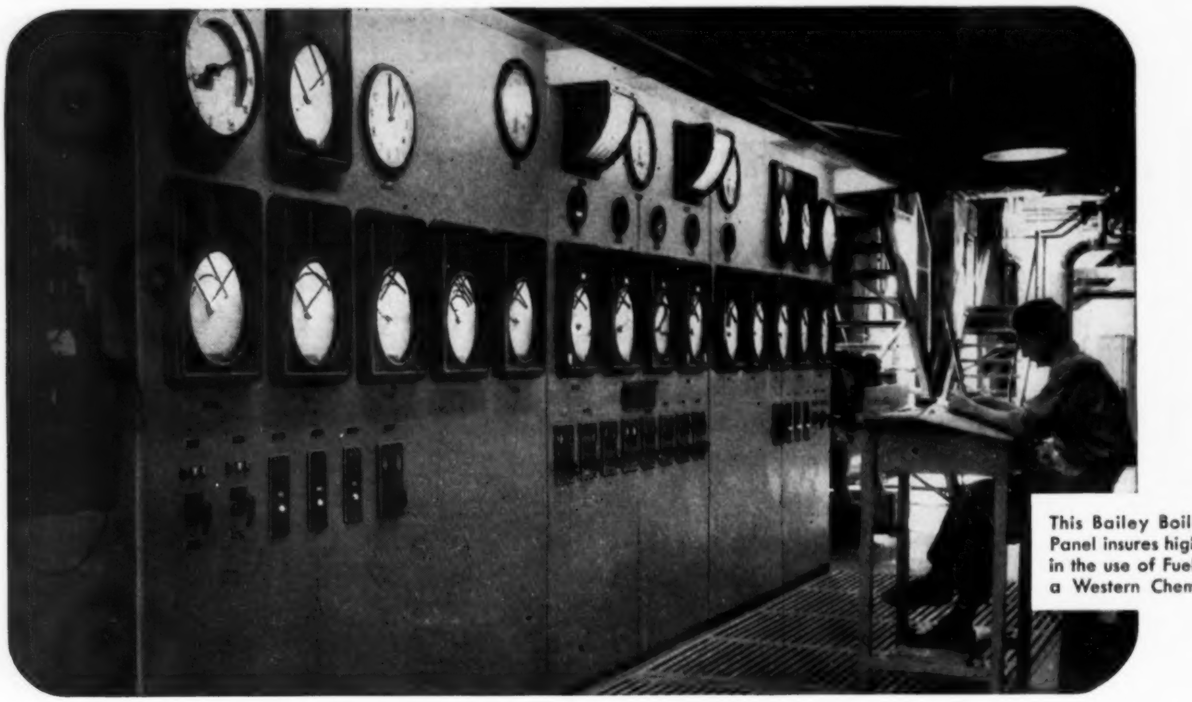

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easy to exaggerate the direct assistance it would be able to give the Commission. Its principal value would be in educating the electric industry, through reports. Membership of ten to fifteen individuals, drawn from top executive ranks with a substantial portion having some engineering background and staggered terms of service are recommended.

As contacts develop along the lines mentioned, further measures of mutual value will suggest themselves. Additional proposals like the current Detroit Edison reactor feasibility study should be welcomed to the extent that the conduct of such studies does not infringe on other pressing AEC work.

Basic Research Stressed

Calling for government aid for fundamental scientific and engineering studies, Dean A. A. Potter of Purdue University told members of the American Society for Engineering Education on June 26 that basic research, on a scale commensurate with the dominant position of the United States in applied research and invention, is essential to protect the industrial and technological competence of our people.

Dr. Potter spoke at a general session of the Society on the National Science Foundation, of which he is a board member. The Foundation, he said, is undertaking to promote and support basic scientific research in mathematical, physical, medical, biological and engineering sciences. Its primary responsibility will be to develop a sound national policy for the promotion of basic research and education in the sciences. A second task will be to evaluate the need for research in the various scientific fields and to provide emergency support in the directions of greatest need.

Speaking of the need for basic research, he continued:

"America's present industrial supremacy may be traced largely to the fact that this country has had a type of government which has encouraged its people to invent, to translate their inventions into marketable products, and to manufacture such products in quantity and at a cost such as to stimulate and satisfy public demand. The welfare of the country in the future, even more so than in the past, will depend upon its scientific and technological developments; and these, in turn, will require people who have ability to create basic scientific knowledge.

"In the past, our inventors were fortunate to be able to draw upon the basic science findings of other countries, mainly European. Our great asset as a nation has been our ability to convert this scientific knowledge into practical utility. Unfortunately, two world wars have greatly depleted the human and material resources of other lands, so that for many years in the future the United States has the responsibility for building up a stock pile of basic scientific knowledge.

"Unless we lay the foundation of basic research for the practical discoveries and inventions, we shall fall short in the future as a creative people.

"We have reached a stage of such complexity in scientific endeavor and cost of

(*Continued from page 63*)

equipment necessary for basic research is so great that universities and private research foundations have insufficient resources to go forward speedily in creating new knowledge. Thus government aid for basic research is essential. In so far as industry is concerned, there is a limit to the amount it can expend for long-range basic research projects. Many American industries are well equipped to invent and carry on programs of basic as well as of applied research, but few have the means for basic research which has a remote connection with immediate gains."

This need for basic research is not confined to the so-called "pure" sciences, such as mathematics, physics, chemistry and biology, Dean Potter pointed out. "Actually, many of the problems now confronting industry and the engineering profession cannot be solved without new basic engineering knowledge." As examples he cited the need for more detailed knowledge of the mechanism of combustion, of the way chemicals may react together on surface contact and in other fields such as the mechanics of fluids, elasticity, electronics and heat conduction.

Unsaturated Hydrocarbons Contribute to Smog

Unsaturated hydrocarbons are the major uncontrolled source of smog in Los Angeles County, according to Air Pollution Control Director Gordon P. Larson who, in a report to the Board of Supervisors, states that all other major sources of smog have been identified and are gradually being controlled. They include dust, fumes and products of combustion, which have been decreased approximately 40 per cent since 1948, and sulfur dioxide, which has been reduced to below the 1940 level. The unsaturated hydrocarbons, which react in the air under the influence of sunlight to produce crop damage, also contribute to eye irritation and reduce visibility. Investigations are now being made to determine the extent to which they are entering the atmosphere in certain areas and how they react in the air to form their portion of smog. This program should indicate how these important contaminants can be controlled.

Mr. Larson stated further that public officials, civic organizations, the press and industry have been most cooperative in smog control, industry alone having spent over $5,000,000 for control equipment in the past two years and current construction involves $1,500,000.

Taking note of the fact that industrial expansion in Los Angeles County during the first five months of this year has been equal to that for the entire previous year, he observed that the facilities of the Air Pollution Control District will be heavily pressed to prevent excessive discharges which would intensify the smog problem. He warned that adverse weather conditions may still produce annoying smog this fall despite the large tonnages of pollution that have been prevented from entering the air.

Ash Handling at Jamestown

At the recently completed addition to the steam power plant of the City of Jamestown, N. Y., a Beaumont Birch Vac-Veyor ash-handling system was installed. Ash and fly ash are collected in dry condition from the hopper bottom of the pulverized-coal-fired boiler and from two hoppers under the superheater passes. Other points of collection of fly ash, soot and dust are located at the base of the stack and underneath the electrostatic precipitator.

The refuse material is conveyed in a dry condition by means of vacuum through pipes from the intakes to a receiver on top of an ash-storage silo. The vacuum is created by a steam exhauster.

Since collection points are located in the basement and on the roof of the power plant, some form of remote control was required for operation. Automatic sequential control, operating from a control panel located in the boiler room, has been installed. Motor-driven rotary-vane feeders are used to feed the refuse material into the ash line. The control system is so designed that the first rotary-vane feeder is started and runs until the hopper is empty at which time it is automatically stopped and the second feeder is started. In this manner, as each hopper is emptied, the control automatically progresses from one hopper to another until the last hopper is empty, at which time the system automatically shuts off.

From the receiver the ashes, soot and dust drop into the storage silo. A rotary ash unloader operated by push-button control is located underneath the silo.

World's Largest Turbine-Generator

The Philadelphia Electric Company has placed an order with the Westinghouse Electric Corporation for a 200,000-kw turbine-generator, largest single-shaft unit ever to be built. The unit will be installed at the new Cromby Station near Phoenixville, Pa. and will be supplied with steam by a Combustion Engineering controlled-circulation boiler.

The turbine will be designed for steam at an initial pressure of 1800 psi and a temperature of 1000 F, with reheat to 1000 F, and will be a triple-exhaust unit. Together with a 150,000-kw turbine-generator already under contract, it will bring the station's total capacity to 350,000 kw.

Air Pollution Meeting in Detroit

The East-Central Section meeting of the Air Pollution and Smoke Prevention Association of America will be held September 13 and 14 at the Veterans' Memorial Bldg., East Jefferson at Griswold St., Detroit. The subjects planned to be covered include Smoke from Coal and Oil Fired Marine Boilers, Air Pollution Control at Refineries, expert panel and open discussion on Characteristics of an Area-Wide Air Pollution Study, and the Detroit Test for Equivalent Smoke Producing Characteristics of Solid Fuel.

Registration is $2.00, and the meeting is open to all who are interested.

REVIEW OF NEW BOOKS

Any of the books here reviewed may be secured through Combustion Publishing Company, Inc., 200 Madison Ave., N. Y.

Corrosion—Causes and Prevention, Third Edition

By Frank N. Speller

Written with particular reference to the ferrous metals, this book discusses the theory of corrosion and describes the various methods for preventing it. High lights of the new edition are its coverage of cathodic protection and inclusion of the latest available information on biological influences and newly developed corrosion preventives.

Part I describes the known facts about corrosion and its generally accepted electrochemical theory. The controlling factors that contribute to the various kinds of corrosion are described in simple language, free of mathematical and thermodynamical terms, and the author then classifies these types of corrosion according to the controlling factors which act external to the metal, such as temperature, rate of motion, films and coatings, concentrations of dissolved substances, acids, alkalies, oxidizing compounds, etc. He also describes the principles and methods found desirable for laboratory and service testing for corrosion.

Part II consists of eight chapters devoted to a detailed coverage of corrosion prevention in the atmosphere, underwater, in closed water systems, in steam generators, in steam and hot-water heating systems, in the chemical industries, and underground. Pertinent data on the calculation of corrosion rates, conversion tables, additional tests for determining corrosive activity, alloy analysis and a glossary of terms are given in the Appendix.

Dr. Speller is widely recognized for his many technical contributions to corrosion research and for his solution of related industrial problems. From 1926 to 1940 he was director of the Metallurgical and Research Dept. of the National Tube Co. Since then he h^s engaged in consultative work with headquarters in Pittsburgh.

The book, which comprises 650 pages, is priced at $10.

Engineering Thermodynamics

By Herman J. Stoever

Intended as a text for an introductory course in engineering thermodynamics by undergraduate students, this book has a number of features which are intended to improve its teachability. It is divided into three parts, the first two being concerned with the first and second laws of thermodynamics and the third with the application of the principles and methods treated in the first two parts. Included among the applications which are analyzed from a theoretical point of view are steam power plants, internal combustion engines, refrigeration, compressors, turbines, and air conditioning.

The material of the first two parts is treated according to the thermodynamic principles considered. This makes it possible to discuss the properties of both perfect gases and actual fluids at the same time, instead of separately as is the case when the approach to thermodynamics is on the basis of the kind of fluid involved. Another desirable feature is the inclusion of sets of problems immediately following more than half of the 145 articles in the book. Many of these articles have worked out illustrative problems, and answers are provided for about half of the 507 problems, thus making the text also suitable for self-study.

Although intended for an introductory undergraduate course, the text might have been made more useful as a book to be kept for use in post-college days had brief bibliographies been appended to the chapters dealing with applied thermodynamics. It is interesting to note that the author, who has had industrial as well as academic experience, acknowledges his indebtedness to thermodynamic texts by Keenan, Zemansky and Kiefer and Stuart.

There are 458 pages in the text which sells for $5.75.

Gas Turbines

By Harry A. Sorensen

Indicative of the current widespread interest in gas-turbine technology is the appearance of this text which is intended for use in one or two-semester courses at the senior or graduate-school level. Its essential objective is to present a thorough and fundamental treatment of the thermodynamic principles, the elements of design, and the general construction features of the gas turbine. The organization of the text is by topic or function rather than by type of power plant, making it possible to give coverage to the field as a whole. Aircraft gas-turbine engines and jet propulsion, for example, are dealt with throughout several sections according to particular functions.

Sufficient theory of design is included to familiarize the student with the general principles that are employed in the field. Treatment of aerodynamics and gas flow has been minimized in favor of additional descriptive material to give the student a better idea of the construction and arrangement of gas-turbine plants. Operating data are also included to indicate current performance, and there is an interesting chapter on structural design.

The author, whose practical experience evidently has largely been in the field of aircraft turbines, has not neglected stationary gas-turbine plants and has achieved a good balance between these two primary fields of application. Each chapter has a bibliography with significant references to many of the more important gas-turbine papers delivered before engineering societies in the past ten years.

The introductory chapter has some very fine reproductions of photographs of gas turbines now in service, and throughout the text the illustrations are in keeping with the high standards set in the series of mechanical engineering texts edited by Burgess H. Jennings, of which this is another volume. The price of the 460-page book is $6.50.

Nomographic Charts

By C. A. Kulmann

This is a new book containing 92 charts, all designed to simplify the solution of time-consuming computation problems frequently encountered by engineers. Based upon actual problems they enable the user to arrive at preliminary solutions without looking up in numerous tables the values of the various items.

A variety of chart designs are employed, including alignment-type charts, intersection-type (graphical coordinates and curves) and combinations of these two kinds. When the problem involves wide ranges in magnitude of the variables, they are presented with the shortest practical numerical scaling but include auxiliary scalings to take care of the decimal point. Some of the charts, chiefly those on hydraulics, are based upon formulas derived from observations and laboratory tests, or upon correlated data on notably successful designs.

Five categories of frequently used engineering computations are included, namely: Function Scales (mainly exponential); Hydraulics and Hydraulic Equipment; Mechanics; Thermodynamics; and Electrical. There is also a group of general usage charts covering such varied items as reciprocals of reciprocal sums, sinking fund deposits, properties of rectangles, etc.

The author is a consulting engineer specializing in power plants and hydraulics and has employed nomographs in his work for the last 25 years.

The price of "Nomographic Charts" is $6.50.

Hydraulic Transients

By George R. Rich

The latest addition to the Engineering Societies Monographs Series is intended to show how arithmetic integration and trial-and-error arithmetic are applied to the solution of a wide variety of problems in hydraulic transients.

Examples taken from projects actually constructed are used to illustrate the application of arithmetic in solving problems in water hammer, speed regulation, governing stability, water-hammer pressures in pump-discharge lines, differential surge tanks, restricted-orifice surge tanks, navi-

gation locks, and power and tidal canals. A final chapter gives the elements of the graphical method as applied to water-hammer analysis.

Those engineers who are not specialists in hydraulics should not take the word arithmetic too literally, for a considerable number of differential equations are introduced in the development of the theoretical background. However, the solutions are obtained graphically or by arithmetic integration.

The author was formerly chief design engineer of the T.V.A. and is now associated with Charles T. Main, Inc. Most of the examples worked out in the book reflect actual engineering problems, and many of them are linked to bibliographical references throughout the text. The 260-page book sells for $7.

Boiler-Water Treatment Manual

How to apply methods of feedwater treatment that save the Federal Government millions of dollars a year in the cost of fuel and boiler-plant repairs is told in a new Bureau of Mines handbook. The publication, "Boiler-Water-Treatment Manual for Federal-Plant Operators," is a companion book to Bureau of Mines Handbook No. 3, "Questions and Answers on Boiler Feedwater Conditioning." The older publication explains why feeding chemicals into boilers prevents scaling, corrosion and caustic embrittlement and increases efficiency. The new manual tells how to accomplish it for boilers of the pressure range used in most Federal power and heating plants.

Prepared by Louis Goldman, supervising chemist of the Bureau's Boiler Water Service Section at College Park, Md., and including a foreword by J. F. Barkley, chief of the Bureau's Fuels Utilization Branch, the manual was written primarily for operators or engineers of Government-operated boiler plants. However, it is equally applicable to privately owned plants operating at pressure up to about 300 psi and at ratings up to about 200 per cent. Individual plant studies, it says, ordinarily are required for boilers operating at higher pressures and higher ratings than those covered in the Manual.

After describing the two methods of boiler-water treatment—internal, by which the chemicals are fed directly into the boiler, and external, by which the chemicals are added to the water in special water-treating equipment—the manual gives the basic information needed for internal treatment. It also tells how to control corrosion in return lines, and how to prevent corrosion during periods of idleness. In addition, it explains the boiler-water-analysis reports which the Bureau of Mines prepares for various Federal agencies.

The Manual can be obtained only from the Superintendent of Documents, United States Government Printing Office, Washington 25, D. C., for 30 cents a copy. It definitely is not for sale by the Bureau of Mines.

Business Notes

National Aluminate Corp. has promoted H. R. Powers to a newly created position of field manager of its Industrial Department. He is succeeded as manager of the Pittsburgh District by I. A. Clausen.

American Blower Corp. has recently elected J. C. Linsenmeyer vice president in charge of manufacturing and appointed John Brennan chief engineer, E. W. Peterson assistant general sales manager, and Benjamin Ragland manager of its Hydraulic Coupling Division.

Recent changes announced by **General Electric Co.** include: A. T. Chandonnet as manager of its Lynn Turbine Division; C. S. Coggeshall assistant manager and R. S. Neblett manager of sales for the G.E. Turbine Divisions.

The **M. W. Kellogg Co.** has named two new vice presidents—R. J. Wolf, formerly assistant to the president, who takes charge of sales, and D. W. Champlin, formerly general manager of the Equipment Manufacturing Division of Continental Can Co., who will have charge of Kellogg's manufacturing.

Manning, Maxwell & Moore, Inc., has appointed Edwin H. Price Pacific Coast District Manager, succeeding Newton P. Selover, who becomes director of export planning.

Four executive promotions have been announced by **De Laval Steam Turbine Co.** They are James P. Stewart, from executive vice president to president; W. A. Neumann, Jr., as vice president responsible for industrial and commercial sales; H. G. Bauer vice president in charge of engineering as well as manager of marine sales; and C. A. Jurgensen vice president in charge of manufacturing.

Bigelow-Liptak Corp., Detroit, has appointed Otto von Perbandt as its representative in southern Ohio, part of Indiana and all of Kentucky, with headquarters in the Schwartz Building, Cincinnati.

Leeds & Northrup, Philadelphia, has elected I. Melville Stein to the position of executive vice president. He was formerly director of research and later vice president in charge of research.

Dowell Inc., Tulsa, Okla., announces the appointment of Ellsworth D. Hudgens as a development engineer, specializing in cathodic protection for retarding electrolytic corrosion of pipe lines and other buried or submerged equipment. Sale of cathodic protection products has been placed in charge of Herb Walther, Jr.

Edward Valves, Inc., Chicago, recently announced the promotion of Carl W. Nederman from assistant vice president to vice president.

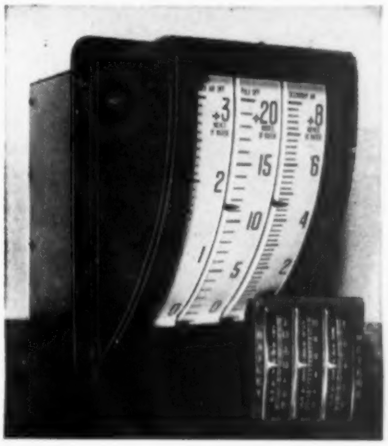
Warren Steam Pump Co., Warren, Mass., is now represented in up-state New York through a recently opened office in Rochester of Process Industries Engineers, Inc., with J. L. Wall in charge.

Baldwin-Hill Co., Trenton, N. J., has purchased the Tex-Rock Insulation Manufacturing Co. The acquisition of this plant at Temple, Texas, in addition to the Company's other factories at Trenton, Kalamazoo and Huntington, Ind., was made to meet the growing demand for insulation products in the Southwest.

NEW EQUIPMENT

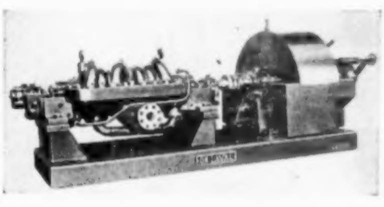
Miniature Instruments

Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, O., has developed a new line of miniature indicators and control units which are being offered under the trade name Mini-Line. Compared to their standard size counterparts, the new indicators and control units save considerable space. The reduction for a new multi-point indicator is 87 per cent, and corresponding values for a selector valve and a remote manual relay are 52 and 70 per cent, respectively. A three-unit multipoint indicator is only $4^1/_4$ in. wide and $4^3/_4$ in. high as compared to measurements of $10\ ^7/_8 \times 14\ ^1/_8$ in. for its standard size counterpart. These instruments make it practical to concentrate into a small space before a single operator all information and controls for operating one or more boilers, turbines or process units.



Opposed-Impeller Pumps

A new line of multi-stage opposed-impeller pumps designed for service up to 1000 gpm and 1200 psi and for temperatures of 350 to 400 F is announced by the De Laval Steam Turbine Co., Trenton 2, N. J. Known as the "Oppeller" pump it has a horizontally split casing with suction and discharge nozzles on opposite sides of the lower half of the casing. Impellers are mounted back to back to balance axial thrust and the volutes are staggered 180 deg to balance radial thrust. Uses include boiler feed and oil refinery services.

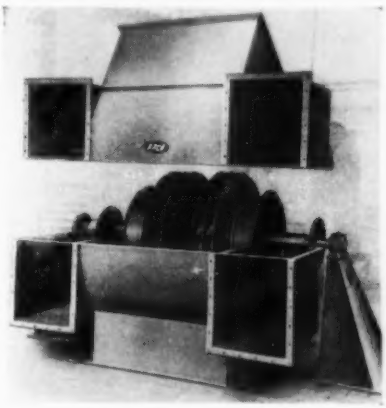


Ion-Exchange Unit

Development of a "Dual Bed" ion exchanger has been announced by the Permutit Company, 330 W. 42nd St., New York, N. Y. The unit which may be used for water treatment in steam heating plants is said to eliminate the need for much elaborate equipment and for handling such chemicals as caustic soda, sulfuric and hydrochloric acids during regeneration. Employing new type resins that are regenerated with plain salt, the exchanger provides water softening and lowers or removes alkaline content and sulfates.

Forced-Draft Fan

Latest development of the Prat-Daniel Corp., South Norwalk, Conn., is a forced-draft fan having new features that improve aerodynamic characteristics and make possible more efficient conversion of velocity to static pressure. These improvements are obtained by the use of (1) large, deep inlet cones to reduce turbulence at the inlet; (2) open space between the wheels of double-wheel models; and (3) an oversize housing to aid diffusion.



Heat-Resistant Alloy

In line with the company's policy of conserving nickel supplies during the current emergency period, The International Nickel Co., 67 Wall St., New York 5, N. Y., has announced the development of an alloy under the trade name Incoloy for use under conditions of high temperature and corrosion. The material contains about 35 per cent nickel, 20 per cent chromium, and the remainder iron. It is produced in most standard rolling mill forms, including sheet, strip, rod, wire and tubing. This alloy is designed for many purposes now served by metals running up to more than 70 per cent nickel.

Insulating Cement

Philip Carey Mfg. Co., Cincinnati 15, Ohio, is now producing a new, improved mineral-wool insulating cement called MW-50. Composed of mineral-wool pellets, asbestos fibers, bonding clay and rust inhibitor, it is especially adaptable to large monolithic construction on furnace walls, stills, tanks and boilers. The material, which can be applied with a trowel and bonds well to cold or hot metal surfaces, can also be used to insulate odd or irregular shaped surfaces, grouped fittings and process equipment.

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